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PRACTICAL

CHEMISTRY FOR FARMERS

AND

LANDOWNERS.

By JOSHUA TRIMMER, F.G.S.,

AUTHOR OF PRACTICAL GEOLOGY AND MINERALOGY.

LONDON:
JOHN W. PARKER, WEST STRAND.

M.DCCC.XLII.

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PREFACE.

UNTIL the publication of Dr Liebig's Report to the British Association for the Advancement of Science, on the application of Chemistry to Agriculture and Physiology, the state of Agricultural Chemistry might be compared to that of Astronomy before the time of Newton; it was too much encumbered with assumption to make any real progress, or to produce any practical results. Those assumptions are now swept away like the crystalline spheres of the older astronomers; and they who would establish a rational and improved system of agriculture on a scientific basis, may proceed with the firmest conviction that the fertility of the soil, whether natural or induced, depends on the inorganic substances contained in it,—on the proportion of the alkalies and alkaline earths, in combination with the silicic, sulphuric, hydrochloric and phosphoric acids,—that plants take up their carbon only in the form of carbonic acid, and that in a state of nature they derive their

Many of the present generation of farmers, while they profess their ignorance of chemistry, are ready to admit that it may be able to do something for them; many of the next generation will themselves be chemists. There is no class of men—if we except the landowners—who have better opportunities for the cultivation of science, and, with the same exception, there is no class who more grievously neglect them. Some there are, too old to learn any thing new, and satisfied with the well-earned celebrity which they have acquired by the practice of empirical agriculture, who proclaim their contempt of all endeavours to raise it to the rank of a science, and exclaim, when you talk to them of Liebig: "It is all nonsense, I had Davy down here humbugging with his chemistry." But the number of these is daily diminishing, as well as of the worshippers of the mysterious principle—they know not what it is—which they have enshrined in farm-yard dung, who while they proclaim that much of its virtue depends on the food of the animal, will not condescend to inquire into the nature of the substances contained in that food—in the corn and beans and oil-cake, which by their own confession contribute so much to the glory of their idol.

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PART I.

THE RUDIMENTS OF CHEMISTRY.

INTRODUCTORY SECTION.

Proverbial repugnance of farmers to innovation—for very good reasons—experimental agriculture the proper work of landlords—increased disposition of farmers for improvements—report of a debate in a farmer's club—their experiments require scientific direction — Liebig on the application of Chemistry to Agriculture—plan of this present work.

Repugnance of Farmers to innovation.

OF all the improvements which have taken place in British Agriculture during the last century, few have originated with practical farmers. They have been adopted by them, it is true, but it has been slowly and reluctantly; and when adopted they have been adhered to with the same pertinacity as the old practice which they superseded. The farmer of the present day considers his mode of cultivation perfect, and plumes himself on his four or six-course rotation, by which the soil is maintained in a state of fertility by the alternation of green with white crops. His grandfather considered this a grievous innovation, and held that no good wheat had been grown since the abandonment of the antiquated system of three crops and a fallow. His grandson, on the other hand, will wonder that in applying the animal excrements which constitute farmyard manure, he should have systematically deprived

them of the greater part of their fertilizing properties before he laid them on the land; that he should so utterly have neglected the most powerful manure of all—human urine; and that he should have been at the expense of carting from one extremity of a large and hilly farm to the other, many tons per acre of rotten dung, when the same results might have been obtained by means of a few hundred weights of certain cheap salts.

It is the same with mechanical improvements of the implements used in agriculture. Every district has its favourite plough, handed down from father to son from the rudest times, and constructed in apparent defiance of some of the plainest principles of mechanics. Improvements in the construction of ploughs are effected, which render them capable of performing their work as well or better, and with a smaller expenditure of labour; but the workmen who have been accustomed to the old implements cannot hold the new, and the farmer does not like them. "Your little kicketing ploughs," he tells you, "may do very well on the light lands of Norfolk, or even on the clays of Essex, but they will not do *here;* and as to your two horses, we find quite enough to do to plough our land properly with four." As well might they lock the wheels of their waggons and carts, and then insist on the necessity of an increased number of horses to draw them; or take the edge off their carving knives, and contend that nothing but blunt knives, and plenty of strength, will cut meat properly. And yet the ploughs of improved construction slowly make their way, and become the established plough of the district; and men are now working their land with two horses, who, when the first implements of the kind made their appearance in their neighbourhood, twenty years

ago, allowed the farmer who used them three years only before he would be dragging them along the surface of the ground.

It was the same with the improved breeds of cattle. The new Leicesters, and the Short-horns, had to contend with much prejudice in every fresh district in which they came in contact with the native races, which they have superseded. They have now become such idols of butchers and graziers, that practical men give fancy prices for them, and the current of prejudice appears to be so far taking the opposite direction, that the valuable qualities of some of the unimproved breeds by which they are adapted to their native districts appear too much overlooked in the prevalent rage for producing the greatest quantity of tallow in the shortest possible time.

Reasons of this repugnance.

This repugnance to depart from established usages if kept within due bounds is far from blameable. The operations of farming must, from their very nature, be a work of routine. The farmer is called on, under the most favourable circumstances, for constant and laborious attention to minute details, connected not only with the cultivation of his land, but with buying and selling. In order that the work of his farm should be well performed, it is necessary that each servant should know his place, and be expert in his peculiar department. This expertness is only attained by practice; and if the nature of his employment be frequently changed, he will require constant instruction in the new operations which he has to perform; and an additional weight of personal attention and responsibility will thus be thrown on the master.

A farmer who has overcome his own prejudices, has to contend with those of his servants, who would often be better pleased that his experiments, as causing trouble to themselves, should fail than succeed. He has also arrayed against him the prejudice and ridicule of his neighbours, and sometimes of his landlord, who, despising every thing bearing the name of science, and himself little versed in the details of practice, holds what he calls a theorist in the most sovereign contempt, and looks up with veneration to the most absurd dogmas promulgated with an air of authority by a practical man.

Experiments must, likewise, in some degree, derange the regular economy of a farm; if conducted on a large scale they are hazardous; if tried on a small scale they require much trouble and attention in the separate harvesting, and weighing or measurement of the crops, without which precision the experiments are in most cases utterly worthless.

The farmer, moreover, hires his land on the calculation that he shall realise a given profit by cultivating it according to an established system of husbandry, and he acts more prudently by adhering to that system, than by seeking a larger profit from another, dependent on the result of uncertain experiments.

Experimental Agriculture the proper work of Landlords.

The improvement of agriculture by means of experimental farming, should therefore be the work, not of tenants but of landlords. If the experiments fail in their hands they can afford the loss; they will ultimately derive most benefit from their success, and though success will, perhaps, in the first instance be

attributed to strength of purse, and to an outlay disproportioned to the profit derived from it, which none but gentlemen can afford, and which would not answer for those who have to make a living by farming, yet, after a time, some practical man, bolder than his neighbours, will adopt the practice resulting from these successful experiments; it will be seen that in his hands it is profitable; one by one his neighbours will follow his example, till in time it will become the established practice of a large district, and will eventually spread over the whole kingdom.

Experiments in farming are of two kinds: those which have for their object the introduction of new modes of cultivation, based on scientific principles, but which have not yet anywhere been reduced to practice; and those which have for their object the extension of superior systems of practice, which have long been attended with success in other districts, under similar conditions of soil and climate. The former would be best carried on upon farms devoted exclusively to experiment, supported by the subscriptions of associated landlords, and managed by men, of whom plenty might be found, familiar with the details of practical farming, and with the principles of science; and now that the aptitude of the improved breeds of cattle to fatten has been so well ascertained, and the principles on which improvement of that kind should proceed are so well understood, the funds of Agricultural Societies would be better employed in experiments such as these, than in giving prizes for sheep and oxen, made so fat that nobody can eat them; or they might be tried by a number of landlords, and the wealthier tenants individually, acting under the direction of a committee of the Royal Agricultural Association, by whom the con-

ditions of the experiment should be laid down so as to obtain uniform results, and to test the accuracy of the theoretical views which it is sought to establish or to refute. The result of such experiments should in all cases be determined by weight and measure, not by loose estimates; and to render them valuable to science, they should always be accompanied by the best possible analysis of the soil on which they were tried, and of the crops produced on it.

The second class of experiments, which have for their object the extension of improved modes of management which have stood the test of long experience in other districts, are more than the majority of farmers can be induced to make, and are those to which most of the cultivators who are disposed to deviate from the beaten track will do well to confine themselves. The trial of that which succeeds in the next field to your own, and which is more than many will venture upon, scarcely deserves the name of an experiment.

Increased disposition of Farmers to adopt improvement.

But by whomsoever experiments are to be made, it is certain that to be of any use they ought to be conducted on some fixed principles, instead of upon the plan of try *any thing*, and if that does not succeed, try any thing else, or try nothing, and conclude your present system of management perfect. The movement of mind by which the present age is distinguished, has communicated itself to the farmers, and within these few years practical men have shewn a greater inclination, not only to adopt improvements, but to take the lead in them; and a growing disposition is manifested by them to invoke the aid of

science. In proof of this, it is only necessary to refer to the crowds in which they flock, from all parts of the kingdom, to the annual meetings of the Agricultural Association, where they mix with Professors of geology, chemistry, botany, and zoology—where their ears, at least, become familiar with such terms as oxygen, hydrogen, carbon, and nitrogen; gluten and albumen, vegetable tissue, and muscular fibre; and where they learn that farming consists in aiding those natural processes by which nitrogen is converted into corn and beef. We might also refer to the numerous farmers clubs instituted in most agricultural districts, and the discussions raised at those meetings on new modes of cultivation—new at least to them, for most of them have long been practised with success in other counties, not an hundred miles distant. It is not a little amusing to hear some of the older farmers who have been prevailed on to join these clubs, excuse themselves for so doing by maintaining their conviction of the inutility of such meetings and discussions *for them*, though perhaps, "the young ones" may learn something, by listening to the combined experience of all the agricultural sages of the neighbourhood, instead of deriving their sole knowledge of the art and mystery of farming from their fathers and grandfathers.

Report of a debate in a Farmer's Club.

The course which such discussions take, renders it evident that the experiments made are generally conducted on no fixed principles, but are for the most part under the guidance of blind chance. Be the subject under consideration the use of liquid manure, or of the nitrates of soda and potassa, or of ground bones or gypsum, the debate almost invariably takes the follow-

ing course. Mr Hopkins has tried the manure in question, and derived no benefit from it. Mr Smith, on the other hand, announces the brilliant success of his experiments with it. Mr Brown declares his experience to be the very reverse of this; and to coincide with that of Mr Hopkins, "liquid manure" he says "is liquid nonsense," and a few loads of rotten dung are worth all the nitrates of soda and potassa in the creation. This Mr Grainger as stoutly denies, and so the discussion proceeds to the extent of at least a dozen speakers, when the chairman sums up with becoming impartiality, by declaring, with Sir Roger de Coverly, that there is a great deal to be said on both sides. Should the subject before them, however, be the merits of two-horse ploughs, the course of the debate will be so far different that they will be condemned by acclamation, one, or, at the most, two farmers having the hardihood to defend them; and it will generally be found, that these are not natives of the district, but have been brought from Norfolk, or Northumberland, by some improving landlord.

Agricultural experiments require scientific direction.

With respect to the discordant results announced by these different experimenters, they may be traced to a difference in the conditions under which the experiments were made. The soil in one case was deficient in the elements contained in the substance employed; in the other, it contained them in as large quantities as the crop raised could take up; or, the crop in the one case consisted of a plant into the composition of which those elements enter but sparingly, while in the other they were required largely; or in the manure applied, two substances required by the crop were present while two more were deficient. *Experiments of the kind, to*

be conducted properly, require a knowledge of the constituents of the soil and of the plants to be raised on it, and a knowledge of what portion of those constituents they derive from the soil and what portion from the atmosphere. To communicate this knowledge in a plain way is the object of the following pages.

Liebig on the application of Chemistry to Agriculture.

Dr Liebig, of Giessen in Hesse Darmstadt, is reckoned the first organic chemist in Europe. By organic chemistry is meant that department of the science which investigates the chemical constituents of plants and animals. At the request of the British Association for the Advancement of Science, Dr Liebig has published a Report on the present state of organic chemistry, in its application to Agriculture and Physiology. Valuable as this report is, it is of too scientific a character for those readers for whose use these pages are intended.

Plan of this work.

I propose, therefore, to lay before them an outline of its contents, in popular language, with such explanations as will bring them down to the comprehension of the most unscientific reader, who will only bestow on the subject the necessary attention. The First Part will be devoted to an explanation of so much of the rudiments of Chemistry as is necessary for the understanding of Dr Liebig's views; and the Second Part will contain the results of his investigations, as to the sources from which plants derive the elements which enter into their composition; and will treat of the practical application of those results to Agriculture.

SECTION II.

ELEMENTARY SUBSTANCES.

Simple and compound bodies—processes by which decomposition is effected—laws of combination—enumeration of simple bodies—gases—oxygen—hydrogen—nitrogen—chlorine chemical nomenclature—non-metallic solids—sulphur—phosphorous—carbon—silicon.

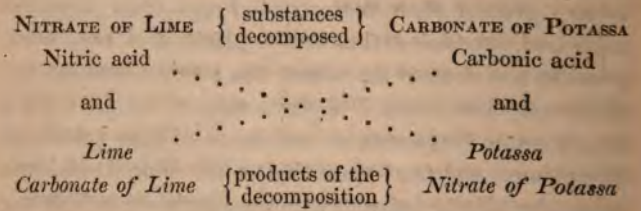
All the substances, organic and inorganic, which exist in the world, are composed of 55 bodies variously combined, which chemists call *elementary* or *simple*, because, as far as we know at present, they consist of only one substance, and all the resources of the laboratory have been inadequate to decompose or reduce them to more simple forms. It is necessary here to explain what is meant by decomposing a substance or reducing it to its elements. A lump of chalk, or a piece of wood are compound bodies. The chalk is carbonate of lime, and consists of carbonic acid and lime,—but neither of these is an elementary substance; carbonic acid is composed of carbon and oxygen;—lime, of calcium and oxygen. The ultimate elements of carbonate of lime, therefore, are carbon, oxygen, and calcium, none of which chemists have yet succeeded in reducing to two or more substances. The elements of wood, again, are carbon, oxygen, and hydrogen.

There are various processes by which decomposition is effected. The decay or putrefaction of animal and vegetable substances are natural processes of decomposition, by which their elements, oxygen, hydrogen, nitrogen, and carbon, are set free to enter into

new combinations. Substances are also decomposed by the action of heat. The combustion or burning of wood or coal is a process of decomposition. During combustion their hydrogen is set free and inflamed, and their carbon, entering into combination with the oxygen of the atmosphere, forms carbonic acid. Lime-burning is another instance of the decomposition of a compound substance by means of heat. During the process carbonic acid is driven off, and quick lime—oxide of calcium, remains in the kiln. Decomposition also takes place when two compound bodies are brought into contact. If the elements of the one have an affinity or tendency to unite with the elements of the other, greater than that which keeps their elements together, mutual action takes place, and new compounds are formed in which the same elements are differently combined. If, for instance, we put into a retort some fragments of carbonate of lime (chalk or limestone,) and pour upon them some diluted sulphuric acid, the affinity between lime and carbonic acid being weaker than the affinity between lime and sulphuric acid, the sulphuric acid combines with the lime and remains in the retort, as sulphate of lime, and the carbonic acid is expelled in the form of a gas. It may be known by a peculiar odour, and by its changing to a red colour (like almost all acids,) paper tinged blue by tincture of litmus.

Instead of allowing the carbonic acid to escape, let the beak of the retort be plunged into a vessel of water, and bubbles of carbonic acid will be seen to rise through the water. By means of an apparatus called a pneumatic trough, which will be described hereafter, this gas may be collected in bottles and jars, and its properties examined.

In the above experiment, sulphuric acid and carbonate of lime were employed. Only one of the substances was decomposed; sulphate of lime remained in the retort, and carbonic acid was set free to mix with the atmosphere, and enter, in the course of time, into new combinations. Let us now take an example in which four affinities are called into play by mixing two compound bodies, and double decomposition takes place, with the formation of new compounds in which the same elements are differently combined; if, for instance, we mix solutions of nitrate of lime and carbonate of potassa, and consisting of



the affinity or tendency to unite, which keeps together the nitric acid and the lime, and the carbonic acid and the potassa, being weaker than that subsisting between nitric acid and the potassa, and the carbonic acid and the lime, mutual re-action takes place, the original compounds are decomposed, and two new compounds produced, viz. carbonate of lime and nitrate of potassa, the weight of which will be equal to that of the original substances employed.

Decomposition also takes place when the substance to be decomposed is brought in contact with the wires connecting the opposite poles of a galvanic battery.

By all these processes then, namely,

1. By the decay and putrefaction of animal and vegetable bodies;

2. By combustion or the action of heat;

3. By the different degrees of affinity existing between the elements of compound bodies brought into contact; and

4. By the action of electric or voltaic currents, bodies are decomposed, and new compounds formed. The chemist, in conducting his researches into the elements, or simple bodies of which compound bodies consist, chiefly employs the three latter; of these voltaic action is the most powerful, effecting the decomposition of substances which had long resisted all other modes of attack.

By means of a strong voltaic current Davy succeeded in decomposing the alkalies, potassa and soda, and the earths, lime, magnesia, &c. which had, till then, been deemed simple bodies. Its feebler action pervades all nature, and produces effects both in the organic and inorganic world of the utmost importance, but respecting which we have yet much to learn.

By the natural processes of decomposition, hard and barren rocks are converted into fruitful soils—soils yield part of their elements to plants—plants are converted into animal substances, and animals, dying and turning to decay, furnish the elements of plants again. The poet has told us—

> Imperial Cæsar, dead, and turned to clay,
> May stop a gap to keep the wind away.

The chemist pursues the metamorphosis further, and sees the particles of nitrogen which once were Cæsar entering into the composition of a load of hay or a sirloin of beef, and contributing to increase the bulk of a prize ox,—a portly alderman, or a jolly farmer—

"we feed all things for ourselves, we feed ourselves for worms."

LAWS OF COMBINATION.

But though all organic and inorganic bodies are combinations of a few simple, or elementary substances, such combinations take place under certain fixed laws. These limit the number of compounds, which would otherwise be as numerous as there are possible combinations of fifty-five (or perhaps more) different substances. In the first place, certain of these elements have no affinity for each other, and do not combine at all; and those which have an affinity, combine only under the following conditions.

1. *The composition of bodies is fixed and invariable.*

A compound substance always consists of the *same elements united in the same proportion.* Its characteristic properties cease when the proportions of its elements vary, and a new compound is the result possessed of different properties.

Carbonic oxide always consists of 6 parts by weight of carbon and 8 of oxygen. A compound of 6 carbon and 16 oxygen constitutes carbonic acid, and possesses properties very different from those of carbonic oxide.

2. *The relative quantities in which bodies unite may be expressed by proportional numbers.*

In whatever proportion, by weight, one body combines with another, it preserves the same relative proportion in all its combinations. This is called its *combining proportion or equivalent*, and sometimes

its *atomic weight*. In determining this proportional number, it is necessary to assume some standard as unity. English chemists have adopted hydrogen as this standard, and as, water, the most simple compound of hydrogen and oxygen, contains 8 parts by weight of oxygen to one of hydrogen, the combining proportion of the latter is 1, and of the former 8; and in these proportions, or multiples of them, they combine with other bodies. Eight parts of oxygen unite with 1 of hydrogen, 16 of sulphur, 20 of calcium, 24 of sodium, 40 of potassium.

Compound bodies have likewise their combining proportions or equivalents, which may be expressed in numbers. The equivalent of sulphuric acid is 40, namely, sulphur, as above, 16, and oxygen 24, or three equivalents. The equivalent of sulphate of lime, again, is 68, namely, sulphuric acid 40, and lime 28 (calcium 20, oxygen 8.)

3. *When a body* A *unites with another body* B *in two or more proportions, the quantities of the latter, united with the same quantity of the former, bear to each other a very simple ratio, which may be represented by one or other of the following series.*

1st series, A, unites with 1, 2, 3, 4, 5, &c. equivalents or doses of B.

2nd series, A, unites with 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. equivalents of B.

Carbonic oxide and carbonic acid afford examples of combination according to the first series.

	Carbon.	Oxygen.	Ratio.
Carbonic oxide consists of	6	8	1
Carbonic acid	6	16	2

In the first case one equivalent of carbon unites with

one equivalent of oxygen; in the second it unites with two equivalents.

The protoxide and peroxide of iron affords examples of combination according to the second series.

	Iron.	Oxygen.	Ratio.
Protoxide of iron consists of	28	8	1
Peroxide of iron.....	28	12	$1\frac{1}{2}$

in which one equivalent of iron unites with 1 or $1\frac{1}{2}$ of equivalent of oxygen.

These laws, which constitute the doctrine of definite proportions, are of the utmost importance. They form a most valuable aid to the memory with respect to the constitution of a numerous class of compounds, which may be easily calculated by remembering the equivalents of a few elementary substances. They assist the practical chemist in determining with certainty and facility the exact quantities necessary to produce a given compound; and they furnish means for testing the results of analysis, and, in some cases, of determining, by calculation, the composition of a substance even before an analysis of it has been effected.

THE SIMPLE BODIES DESCRIBED.

I have said that the number of simple, or elementary substances, at present known, is fifty-five. The number, however, is continually varying. Frequent additions are made to the list by the discovery of some new metals, more rarely, by the discovery, as in the case before mentioned, of the alkalies and earths, that some, which had previously been considered simple, are, in reality, compound. Some few are now suspected by the chemist to be compound; but as their decomposition has never yet been effected, we are compelled in

the present state of our knowledge to regard them as simple.

The simple bodies may be classed in the following manner, namely:

Five gases, or vapours: *oxygen*, *hydrogen*, *nitrogen*, *chlorine* and *fluorine*.

Eight non-metallic solids and fluids: sulphur, *phosphorus*, selenium, iodine, bromine, boron, *carbon*, and *silicon*.

Three metallic bases of the alkalies: *potassium*, *sodium*, lithium.

Four metallic bases of the alkaline earths: barium, strontium, *calcium* and *magnesium*.

Five metallic bases of the earths: *aluminum*, yttrium, glucinum, zirconium and thorium.

Thirty metals, such as gold, silver, iron, &c., the names of which I shall not enumerate, as, with the exception of iron, they are not of much importance in that department of chemistry under our consideration. The elementary substances of most consequence to our present inquiries, are those printed in italics in the above list, namely, oxygen, hydrogen, nitrogen, chlorine, sulphur, phosphorus, carbon, silicon, potassium, sodium, calcium, magnesium and aluminum.

THE GASES.

Oxygen.

Oxygen, in its uncombined state, is a permanently elastic, invisible gas, without taste or smell. By permanently elastic is meant, that by no compressing force or degree of cold, hitherto applied, has it been condensed into a liquid or solid state. It is never met

with in nature except in combination with other bodies. For some of them it has so strong an affinity, that it is separated from them with the greatest difficulty. It has so general an affinity for most substances, and enters so largely into their composition, and its compounds form so large a portion of all rocks and soils, that it is supposed to constitute nearly one-half of all the ponderable matter composing the exterior parts of the globe.

	Parts by weight.			
In silica, or the earth of flints	8 out of 16 are oxygen.			
In alumina, or the earth of clay ..	24	...	51	.....
In magnesia	8	...	20	.....
In lime	8	...	28	.....
In potassa.	8	...	48	.....
In soda	8	...	32	.....
In carbonic acid	16	...	22	.....
In sulphuric acid ...	24	...	40	.....

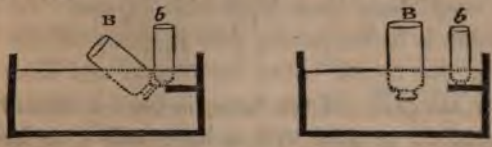
A large portion of the atmosphere consists of oxygen, deprived of which it loses its power of supporting animal life. Combined with hydrogen in the proportion of 8 to 1 it forms water.

Oxygen, though not inflammable, is a supporter of combustion; every substance which burns in common air burns with much greater intensity in oxygen gas; the glowing wick of a candle, or the glowing cinder of paper, after the flame has been exstinguished, burst into flame again when plunged into oxygen gas. Even iron and steel undergo rapid and brilliant combustion in oxygen. During the process of combustion the burning body, or a portion of its elements, combines

with oxygen. It was at one time supposed that combustion could not take place without the presence of oxygen; but it has been ascertained that there are other supporters of combustion, as chlorine, bromine, iodine and fluorine.

Many persons who are ignorant of chemistry, when they hear of oxygen, hydrogen, &c. consider them as mere creatures of the imagination, or as they call it, "all theory." I shall therefore describe some of the modes, by means of which, with the aid of a cheap apparatus, these bodies may be obtained from some of their compounds in a separate state, and effects produced which will convince any one who will take the trouble of making the experiment, of the existence of these powerful though invisible substances.

For the purpose of procuring or experimenting with oxygen, it is necessary to be provided with a pneumatic trough, represented in the annexed cut, which is the



section of a trough nearly filled with water (represented by the dotted line,) and having a small shelf, about two inches below the surface of the water, on which bottles or jars may be placed over a hole in the shelf about $\frac{1}{4}$ of an inch in diameter. The use of this apparatus in collecting gases will now be shewn. If we fill a bottle with water, and turn the mouth downwards, the water will escape with a gurgling noise; bubbles of air will rise through the neck of the bottle, and when all the water shall have run out, the *apparently empty bottle will be full of air.*

The air in this bottle may be transferred into another, by means of the pneumatic trough, in the following manner. Fill a bottle or jar quite full of water, by plunging it in the deep part of the trough; then carefully inverting it without bringing its mouth above the surface of the water, slide it on to the shelf and place it with its mouth downwards over the hole in the shelf. Next, plunge the neck of your bottle of air below the water; bring it beneath the other bottle, and on inclining it into the position represented by *B* in the last cut, bubbles of air will escape and rise into the bottle *b*, displaying an equal bulk of water, till it is all removed and the bottle filled with air. If, instead of common air, the bottle *B* had been filled with oxygen, and corked or stoppered up, it would have been necessary, after plunging its mouth below the water to remove the cork or stopper, and to bring the mouth of the bottle below that of *b*, when the latter would have been filled with oxygen. In order to confine it in the bottle, slide it gently off the shelf, keeping the mouth below the water, and insert the cork or stopper. If the latter is used it should have been slightly greased with a little tallow or lard.

Those who wish to examine the peculiar properties of this and the other gases, and would avoid the trouble of preparing them, may purchase them in London at the operative chemists, at about sixpence per gallon; but, as it will impress the subject more on the mind to procure them by decomposing some of the substance containing them, I shall now explain the common method of obtaining oxygen gas from the black oxide of manganese, which may be purchased for three-pence per pound.

Some of this black oxide is to be thoroughly

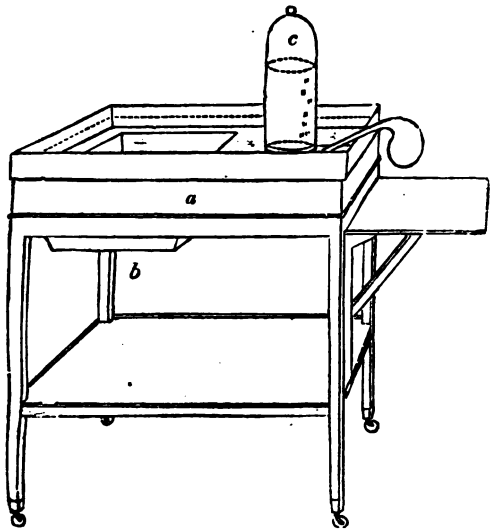
dried on the hob, or, which is still better, on the top of an Arnot's stove (stirring it while drying with a piece of iron wire) till a plate of glass held over it remains quite bright, no moisture condensing on it. Unless this precaution be taken there is a danger that steam, generated during a subsequent part of the process, might produce an explosion. A gun-barrel, of a large bore, is to be procured, the touch-hole of which is to be stopped, by plugging it with a piece of wire. Into this gun-barrel some of the dried manganese must now be poured, till it is nearly half full. It must not be tightly rammed but left loose. Into the mouth of the barrel a cork is to be fixed, which has been neatly and smoothly perforated, first, by piercing it with a brad-awl, and then by enlarging the hole by means of a rat-tail file, till a half-inch pewter gas-tube (which may be procured at any gas-fitters) will fit tightly into it. The joint must be made air-tight by means of a strip of bladder (well soaked in water till quite soft) tied round the end of the gun-barrel near the cork and a little way up the pewter pipe. The pewter tube is next to be bent into this form. The breech-end of the gun-barrel is then to be thrust horizontally into the fire. After a short time a little steam will come over, caused by a small quantity of water remaining in the manganese however well dried, and now expelled by the greater heat. When this vapour ceases oxygen will be given out. Its presence may be known by lighting a piece of paper, blowing out the flame and holding the glowing paper-cinder to the pipe. When this is rekindled it is time to begin collecting the oxygen. To do this, place the pneumatic trough so that the bent tube may dip below the sur-

face of the water, and its end may be just under the hole in the shelf. Fill a bottle, or glass jar, quite full of water; turn it bottom upwards in the water, and gently and carefully slide it on to the shelf, so that its mouth may be over the hole. Bubbles of oxygen will now rise and displace the water in the jar or bottle. If it be intended to keep a supply of gas for future use, wide-mouthed bottles must be used fitted with ground glass stoppers, the stoppers and mouths of the bottles being slightly greased after being well dried, so as to make them air-tight. When one of these bottles is quite full of gas, slide it carefully off the shelf with one hand, and with the other insert the stopper, giving it a slight twist. Tie a piece of cloth over the neck of the bottle to prevent the expansion of the gas from change of temperature forcing out the stopper, and put the bottles into a cool place, where they may be kept for some months. When gas ceases to be evolved, or you have filled as many bottles as you require, remove the trough, bend the tube

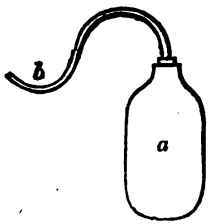
into the annexed form that the water may run out, and, having protected your hand by a strong woollen glove, draw the gun-barrel from the fire and place it to cool, so that the *pewter pipe may hang down*, for if any water should drain back to the hot iron or manganese, the steam suddenly generated would produce an explosion, which would scatter the hot contents of the gun-barrel about and perhaps send some of them in your face.

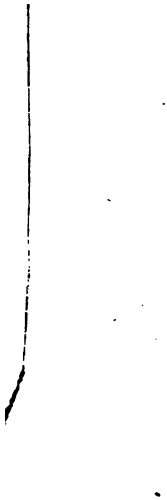
Oxygen may also be prepared from the peroxide or black oxide of manganese by mixing it in fine powder in a glass retort, with about an equal weight of strong sulphuric acid, and heating the retort by means of a spirit lamp, when the gas may be collected

by plunging the beak of the retort into the water of the pneumatic trough, as already described in the case of the gun-barrel. This cut represents a pneumatic



trough, for experiments in which very large glasses are used; *a* is the trough, *b* the well for filling the jars with water, *c* an inverted jar placed over the hole in the shallow shelf. The flap on the side is for placing a lamp under the retort. This cut represents a glass





PRACTICAL

CHEMISTRY FOR FARMERS

AND

LANDOWNERS.

By JOSHUA TRIMMER, F.G.S.,

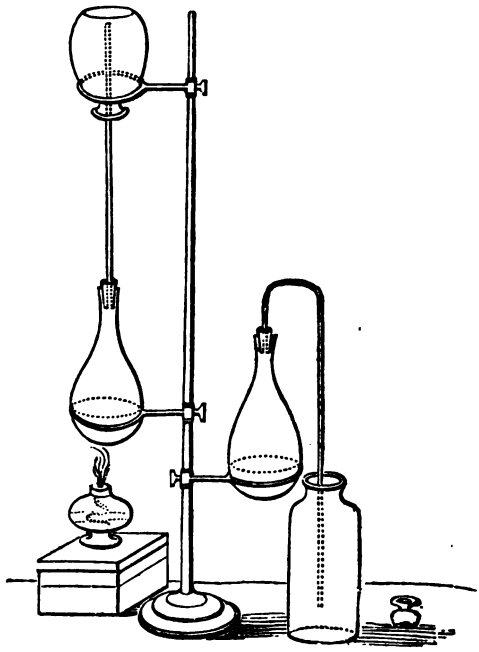
AUTHOR OF PRACTICAL GEOLOGY AND MINERALOGY.

LONDON:
JOHN W. PARKER, WEST STRAND.

M.DCCC.XLII.

788.

gas-bottle for the evolution of carbonic acid or hydrogen, with a curved tube *b* of glass, fitted by grinding into the neck of the flask *a*. This is an arrangement for collecting light and heavy gases, the former on the left, the latter on the right.



The properties of oxygen as a supporter of combustion may be seen in the following experiment. Fasten a piece of wax taper to the short end of a piece of wire bent into a hook thus ⟋⟍. Open one of your stoppered bottles of oxygen, as it stands with its mouth upwards on the table, for the oxygen will not escape, being rather heavier than the air, the flame of the taper will burn with increased dimensions

and greater brilliancy, and on withdrawing the taper, extinguishing the flame, and plunging the glowing wick into oxygen, it will be rekindled.

Though oxygen combining with many other substances produces acids, it possesses no acid properties itself. Dip a piece of blue litmus paper into one of your bottles, it will not be turned red as it would be if an acid were present; neither has oxygen any alkaline properties, though combined with soda and potassium it forms alkalies, for on making a similar experiment with yellow turmeric paper, you will find that its colour is not changed to reddish brown. These are called by chemists *test*-papers, and the operation of trying for acids and alkalies by means of them, or for other bodies by means of different substances which produce characteristic effects, is called *testing*.

Hydrogen.

I now proceed to hydrogen, which derives its name from two Greek words, signifying generator of water, because it is one of the constituents of that fluid. It is the lightest of all known ponderable substances, weighing scarcely more than one fifteenth of an equal bulk of common air. Like oxygen, it is a permanently elastic and invisible gas, highly inflammable, though but a feeble supporter of combustion, and so injurious to animal life as to occasion death when breathed for any length of time. In its pure state it is perfectly inodorous; the disagreeable smell that usually accompanies hydrogen arises from impurities contained in it. The smell produced when hot iron is plunged into water, or water is thrown on burning coals, is occasioned by the liberation of hy-

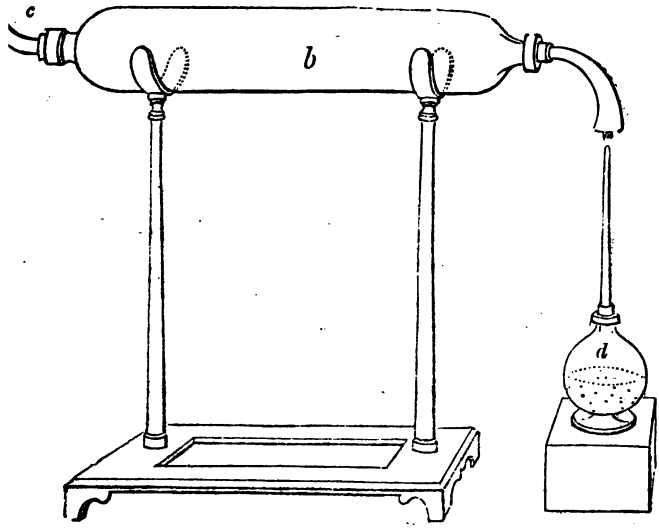
drogen from the water contaminated with some impurities derived from the iron and the coals.

Water is composed of hydrogen and oxygen combined, in the proportion of two parts by *measure* of hydrogen to one of oxygen, or of eight parts by weight of oxygen to one of hydrogen. This has been proved both by decomposing water by means of a galvanic battery, and collecting the two gases, and also by mixing oxygen and hydrogen in the above proportions. The two gases when mixed remain unaltered till compressed into a small compass by means of a condensing syringe, or till an electric spark be passed through them, when they combine with a loud report and a vivid flash. The experiment, however, is dangerous. Combination may be effected more safely by mixing the two gases in a bladder, (*which must be small,*) first squeezed tight to exclude atmospheric air; on pricking the bladder with a needle and applying the flame of a candle to the hole, the bladder will burst with an explosion like that of a pistol.

By neither of these processes can the water resulting from the combination of the two gases be collected; but the mixed gases, if heated at a lower temperature than that at which they explode, enter quietly into combination and water is obtained. Water may also be shewn to be composed of oxygen and hydrogen thus: procure a bottle fitted with a perforated cork, through which a slender glass, or metallic tube, or piece of tobacco pipe is passed; put into the bottle a few small iron nails or pieces of zinc; let them be more than covered with water; and pour in sulphuric acid, about equal to the weight of the metal; and fit the cork and tube in the bottle

so as to be air tight. Hydrogen will be disengaged in abundance; and on the application of the flame of a candle to the jet of gas which issues through the pipe, it will burn slowly and quietly. *Two minutes at least* should, however, be allowed to elapse after closing the bottle before applying the flame, in order that all the atmospheric air in the bottle may first escape, or an explosion will take place.

This apparatus is called the "philosophical candle," and by means of it the production of water by the combination of hydrogen with oxygen, may be shewn in the following manner. While the jet of gas is burning, hold over it a tumbler or glass jar; the oxygen of the atmospheric air combining with the burning hydrogen, will form water which will condense on the glass so long as it remains cool. The annexed figure



represents an apparatus used by chemical lecturers for exhibiting the formation of water; *d* is the philosophical candle just described, by means of which a jet of hydrogen is burned under the copper funnel *a*, and uniting with the oxygen of the atmosphere, produces the vapour of water, which entering the glass cylinder *b* condenses in drops. A current of air passes through the cylinder by means of the curved tube *c*, and allows the escape of the nitrogen which accompanies oxygen in atmospheric air.

This figure represents an apparatus for decomposing water by means of a voltaic current; *a* is a small glass like a wine glass, the sides of which having been perforated, platinum wires *b b*, are firmly cemented into them. The glass is to be filled with water, to which ten or twelve drops of strong sulphuric acid are added to render it a better conductor of electricity. On connecting the platinum wires with the wires attached to the opposite ends of the galvanic battery, numerous small bubbles will issue

from each of the wires. These bubbles may be collected by means of two small glass tubes six inches long, and about a quarter of an inch in diameter *c c*, filled with water, and inverted in the wine glass over the platinum wires, in the same manner that a jar is

inverted in the pneumatic trough. The gas collected in one of these tubes may be proved to be oxygen by its rekindling the glowing cinder of a piece of wood or paper brought in contact with it. The gas collected in the other may be known to be hydrogen by its inflaming when brought in contact with the flame of a lighted paper. By means of this apparatus it will be found that on decomposing a given quantity of water, two volumes or bulks of hydrogen will be collected for one of oxygen. Water may be decomposed and hydrogen obtained by the following method; put a quantity of iron filings into a gun-barrel, from which the breech has been removed, connecting one end of it with the beak of a retort which contains water, and making the joint air-tight by binding over it a strip of wet bladder. The barrel being kept in a bright red heat by being passed through a portable furnace, and the water being made to boil in the retort by the application of a spirit lamp, the steam passing through the gun-barrel will be decomposed; its oxygen will unite with the iron turnings to form oxide of iron, or iron rust, and the hydrogen, set free, may be collected by bringing a bent pewter pipe fixed into the other end of the gun-barrel, (in the manner described in treating of oxygen) under the mouth of a jar or bottle filled with water, and placed on the shelf of a pneumatic trough. Or the hydrogen may be collected in a bladder, from which the atmospheric air has been squeezed by fixing it at the end of the gun-barrel.

Nitrogen.

Nitrogen is another permanently elastic and invisible gas, of great importance in organic chemistry, both as a constituent of animal and vegetable substances, and as entering into the composition of atmospheric air, so essential to their existence. It is also called azote, from a Greek word signifying deprivation of life, on account of the deadly effects produced by it when inhaled into the lungs. This property, however, it possesses in common with several other gases, and therefore nitrogen or generator of nitre is a preferable name.

Nitrogen is not a supporter of combustion, but extinguishes all burning bodies that are plunged in it; neither is it inflammable, like hydrogen, though under certain circumstances it may be made to combine with oxygen.

Incapable, however, as nitrogen is of supporting animal life, the air which we breathe consists of eight parts by weight of oxygen, and twenty-eight of nitrogen. Nitrogen may be obtained for examination by depriving atmospheric air of its oxygen, by the following process. Place a small cup in a soup plate, or other shallow vessel of water, and place in the cup a bit of phosphorus about the size of a pea. Inflame the phosphorus by means of a heated wire, and cover it with a deflagrating glass jar with the stopper removed. Then insert the stopper while the jar stands in the water. It will speedily be filled with white fumes, which consist of phosphoric acid, formed from the combination of the phosphorus with the oxygen of the air in the jar.

This acid is rapidly absorbed by water, and will disappear in half an hour. The gas remaining in the jar will be nitrogen. Sink the plate beneath the water of the pneumatic trough and remove it. Sink the cup to the bottom of the trough; slide the jar on to the shelf, and transfer the nitrogen in the manner before described into another jar filled with water. This is to be repeated several times in order to cleanse the nitrogen from phosphoric acid. Nitrogen may also be obtained by exposing fresh muscle to the action of dilute nitric acid. The nitrogen thus obtained will be contaminated with a little carbonic acid, which may be removed by agitating it with lime water.

Compounds of Nitrogen and Oxygen.

Nitrogen forms with oxygen five distinct and important definite compounds, containing different proportions of oxygen; namely,

Nitrogen.	Oxygen.		
14 parts	8 form	22	Protoxide of nitrogen.
14	16	30	Binoxide of nitrogen.
14	24	38	Hyponitrous acid.
14	32	46	Nitrous acid.
14	40	54	Nitric acid.

The compounds afford an excellent illustration of the laws of combination in definite proportions before spoken of. We see that the quantity of nitrogen remains the same, namely 14 or one equivalent, and that this quantity combines with 8, 16, 24, 32, and 40 parts, that is, with 1, 2, 3, 4 and 5 equivalents or doses of oxygen.

Nitrogen and Hydrogen.

Ammonia. Fourteen parts of nitrogen combined with three of hydrogen constitute ammonia, a gas having the same pungent odour as smelling salts, or spirits of hartshorn. This has an alkaline reaction, restoring its blue colour to litmus paper, which has been tinged red by the action of an acid, and changing the yellow of turmeric paper to brown.

Muriate, or more properly hydrochlorate, of ammonia is emitted from volcanos, but the quantity thus obtained is insufficient to supply the demand. It was once obtained in abundance from the neighbourhood of the temple of Jupiter Ammon, in Africa, and thence received the name of sal ammoniac. It is now made in this country in large quantities for manufacturing purposes. Of itself it is inodorous, but when mixed with quick-lime in a retort and heated, it gives out a gas of the same smell as that produced by the combination of nitrogen and hydrogen. Water absorbs 400 times its bulk of this gas, and acquires some of its properties. Water thus saturated is called liquid ammonia, and is the spirits of hartshorn of commerce. On heating the liquid, the ammonia assumes the gaseous form, and flying off in the state of gas is said to be *volatile*.

Ammonia is found in urine, (combined with a peculiar animal acid called lactic acid, and with phosphoric acid,) in the proportion of 19 parts out of 100 of fresh urine. During the putrefaction of urine the urea and free lactic acid contained in it are likewise converted into ammonia and its salts. These volatile salts of ammonia constitute the great value of stable dung as manure, by furnishing plants with a supply of nitrogen.

This is one of the most important operations of agriculture, for though all parts of plants contain nitrogen in varying proportions, the seeds contain it in the greatest abundance. Without nitrogen straw may be produced but no grain. It will be shewn, hereafter, that in our present mode of applying farm-yard manure, its most valuable properties,—those contained in the urine from stables and cowsheds—are all lost; and that in this country, the benefits which might be derived from human urine, every pound of which is capable of producing a pound of wheat, are totally neglected.

One of the principal distinctions between animal and vegetable matter, consists in the much larger proportion of nitrogen which the former contains. When the recent muscle of animals is acted upon with dilute nitric acid nitrogen is given out abundantly.

Before we proceed further, let us pause to consider the opposite properties of these three gases, oxygen, hydrogen and nitrogen, in their separate state and in their combinations. Oxygen is incombustible, but a supporter of combustion; hydrogen is combustible, but extinguishes the flame of a candle plunged into it. These two gases when mixed in certain proportions, explode and form water, the most incombustible of bodies.

Hydrogen and nitrogen are both poisonous if inhaled into the lungs, yet hydrogen enters into the composition of water so necessary to animal and vegetable life; and nitrogen, mixed with oxygen in the proportion of 28 to 8, constitutes atmospheric air, without which neither of them can exist; while combined with oxygen, so essential to the life of animals, in the proportion of 14 to 54, it produces a corrosive and destructive poison.

Nitrogen and hydrogen again, when pure, are perfectly inodorous and neither of these substances have the power of neutralizing acids; but combined they form a gas of a peculiar pungent smell and possessing alkaline properties.

Chlorine.

Oxygen, hydrogen, and nitrogen, are gases properly so called; they cannot by any degree of cold or pressure be reduced to a liquid state. Chlorine under such circumstances is converted to a yellow liquid, and is therefore a gaseous vapour.

Chlorine may be obtained from hydrochloric (muriatic) acid, which is a compound of chlorine and hydrogen, by the following process. A tubulated glass retort, that is a retort having a glass stopper to it, capable of holding about a pint, is to be nearly half filled with black oxide of manganese. The beak of it being placed just under the hole in the shelf of the pneumatic apparatus, and the body of the retort supported on a retort stand with a sliding ring, which may be adjusted to different heights,—as much hydrochloric acid is to be gradually poured in through the stoppered hole, or tubulure, by means of a glass or earthenware funnel, as will reduce the manganese to a thin paste, and by shaking the retort the acid and manganese are to be thoroughly mixed. Having now inserted the stopper, place a bottle filled with water (the water must be warm, for cold water absorbs chlorine) over the hole in the shelf. Towards the close of the operation, it may be necessary to apply heat to the retort, by means of a spirit lamp, but in the first instance chlorine will be disengaged without heat. Bubbles will be seen to rise through

the water, and to ascend into the bottle. The first that comes over will consist of the common air which was contained in the retort, and may be suffered to escape or rather should be collected in a separate bottle, lest any chlorine should escape at the same time into the room, as it is a noxious substance, producing a pernicious effect on the throat and lungs, even when largely mixed with atmospheric air. This bottle is to be corked up, and taken into the open air, where its contents may be allowed to escape. Another bottle is then to be filled in the same manner with pure chlorine, which may be known by the yellow colour of its vapour.

During the process above described, part of the hydrogen of the hydrochloric acid unites with part of the oxygen of the oxide of manganese and forms water, with evolution of free chlorine.

Chlorine possesses no acid properties;—it neither has a sour taste, nor reddens litmus paper,—and has comparatively but a slight tendency to combine with acids.

It has a powerful affinity for the metals, many of which take fire spontaneously during combination; though a lighted taper is extinguished when plunged into a vessel of chlorine. Antimony reduced to powder and thrown into chlorine burns with much splendour, accompanied by copious white fumes; gold leaf burns in a similar manner, with a fine red light; phosphorus also inflames spontaneously, burning with a pale flame much inferior in brilliancy to that produced by its combustion in oxygen. The products of combustion in chlorine are called chlorides.

Chlorine possesses the property of destroying all animal and vegetable colours, and is therefore used

(principally in combination with lime) for the purpose of bleaching linen and cotten goods. The process however requires much care in its application, as a strong solution of chlorine or chloride of lime not only discharges the colour, but destroys the texture of the cloth.

Chlorine and chloride of lime possesses another valuable property, that of destroying infection, and the effluvia arising from decaying animal and vegetable matter. The process of fumigation with chlorine is thus conducted. Saucers or other earthen pans containing a mixture for generating chlorine, which may either be the black oxide of manganese and muriatic acid, or common salt (chloride of sodium) and sulphuric acid, are to be placed in the upper part of the room which it is desired to fumigate, as near the ceiling as possible, for chlorine is a heavy gas and will sink to the floor. The operator having withdrawn, the doors and windows are to be closed till the evolution ceases. They are then to be opened, and a current of air allowed to flow through the room to carry off the chlorine; after which the process may be again repeated till the room is considered sufficiently fumigated. Care must be taken not to inhale the gas during the operation; and to prevent unpleasant effects from it, it is as well for the operator to hold a sponge saturated with a weak solution of ammonia folded in a handkerchief before his mouth and nostrils, as the ammonia will neutralize the chlorine and prevent its entering the throat.

In the use of chloride of lime as a disinfecting agent, rags dipped in a solution of it are to be suspended in the upper parts of the room. Either process may be used, but the first, though sometimes distress-

ing to the lungs when the chlorine is not removed by a current of fresh air, is the most effectual. The mangers, racks, &c. of stables and cow-sheds in which the glanders or other infectious disorders have broken out, should be washed with a solution of chloride of lime.

The well-known substance, common salt, or chloride of sodium, is the chief constituent of sea water, is contained in many springs, and is found in most soils and in the ashes of plants. The chlorides of mercury afford a striking example of the difference produced in the properties of a compound, by a difference in the proportions of the same elements, the protochloride is that valuable medicine calomel, while the perchloride is the deadly poison, corrosive sublimate.

SECTION III.

DESCRIPTION OF THE SIMPLE BODIES CONTINUED.

Chemical nomenclature—description of the non-metallic solids sulphur—phosphorus—carbon—silicon—metallic bases of the alkalies and earths—potassium—sodium—calcium—magnesium—aluminum.

Chemical Nomenclature.

I have before spoken of acids, and alkalies, and it will be as well in this place to explain by what properties these two classes of bodies are distinguished.

Acids are compounds, capable of combining with alkalies or earthy bases, and when in solution most of

them either have a sour taste or redden litmus paper. Many of them contain oxygen as one of their ingredients; so many that it was once supposed, though erroneously, to be the only acidifying principle.

When a substance forms with oxygen more than one acid, the termination *ous* is used to denote that which contains the least, and the termination *ic* to denote that containing the greatest portion of oxygen; thus we have sulphur*ous* and sulphur*ic*, nitr*ous* and nitr*ic*, phosphor*ous* and phosphor*ic* acids.

Alkalies have a peculiar pungent taste and neutralize acids, that is they combine with them so that the resulting compound has neither the properties of an acid nor an alkali; they change some vegetable blues to green, and change to a reddish brown, paper stained yellow by infusion of turmeric. The blue colour of litmus paper which has been changed to red by an acid is restored by an alkali. This changing the colour of vegetable hues may be regarded as an effect too trivial to be made the foundation of a division of bodies into different classes, but it is of importance as a certain and easy test of the presence or absence of certain peculiar properties.

Salts. The substances formed by the combination of acids with alkalies and other bases are called salts, because most of them have a saltish taste. The salts which have for one of their constituents an acid terminating in *ic*, are distinguished by the termination *ate*; those salts formed by acids containing a smaller portion of oxygen, and terminating in *ous* are distinguished by the termination *ite*; thus we have sulph*ates* composed of sulphur*ic* acid united with a base, and sulph*ites* composed of sulphur*ous* acid and a base; we have nitr*ates*, phosph*ates* and nitr*ites*, and phosph*ites*,

in which the name at once indicates the base and the proportion of oxyen in the acid with which it is united.

Salts are generally disposed to the arrangement of their particles in regular forms called crystallization, and such regular forms are called crystals.

The alkali, earth, or metallic oxide entering into the composition of a salt is called its *base*, and the names of salts and all other compound bodies have been so arranged as to indicate their composition; as for instance, sulphate of lime composed of sulphuric acid and lime, carbonate of soda composed of carbonic acid and soda.

Oxides, Chlorides, &c. Compounds of oxygen, chlorine, iodine, bromine and fluorine with each other and with other elements, such compounds not having acid properties, terminate in *ide*, as oxide of carbon, oxide of iron, chloride of sodium, bromide of phosphorus, fluoride of calcium, iodide of mercury. The most numerous oxides are the combinations of oxygen with the metals. Some metals and other bodies com-

bine with oxygen in two or more proportions to produce non-acid bodies. In those cases the proportions of oxygen contained in each are denoted by uniting with the word the Greek nouns of number; thus we have protoxides and binoxides (sometimes deutoxides), signifying non-acid combinations of a base with oxygen, which contain respectively one or two doses of that element. In the same manner we have protochlorides, protiodides, bichlorides, biniodides, &c. Peroxide, perchloride, periodide, &c. denote those compounds of the metals and other bodies which contain the greatest quantity of oxygen, &c. with which they can unite without producing acid properties; as peroxide of iron, perchloride of phosphorus.

Sulphurets, Phosphurets, &c.—The combinations of sulphur, phosphorus, carbon and selenium with one another and with the metals, as well as of the metals with one another, are distinguished by the termination *uret*, as sulphuret of phosphorus, phosphuret of carbon, carburet of iron, arseniuret of cobalt; and the terms bisulphuret, bicarburet, &c. denote that such compounds contain twice as much sulphur or carbon as the simple sulphurets and carburets, called also protosulphurets and protocarburets, while the terms persulphuret, percarburet, &c. are applied to combinations containing the greatest quantity of sulphur, carbon, &c. with which the bodies composing those compounds can unite.

The basis of this nomenclature or system of names was laid towards the close of the last century by four celebrated French chemists, Lavoisier, Berthollet, Guyton Morveau, and Fourcroy, and has since been extended and modified to keep pace with the advance of the science. Its value is immense as an aid to

the memory with respect to the composition of bodies, which it indicates with precision, the first name pointing out the genus, and the second the species to which the compound belongs. It has therefore superseded almost all the names previously in use, and though some substances, from their importance and the common purposes to which they are applied, have retained the ancient names, yet they have also scientific names indicating their composition; water is oxide of hydrogen, calcium oxide of lime, calomel protochloride of mercury, corrosive sublimate perchloride of the same metal.

Having now described oxygen, hydrogen, and nitrogen, three gases which are of such great importance in the animal and vegetable kingdom, and the gaseous vapour chlorine, and having explained the names used in chemistry, I shall proceed to those non-metallic solids, and those metallic bases of the alkalies and earths which enter into the composition of soils and plants.

NON-METALLIC SOLIDS.

Sulphur.

Sulphur, or brimstone is known to every one. It is insoluble in water, burns with a blue flame, and during its combustion, combines with oxygen and forms fumes which are pungent to the smell, and acid to the taste. These consist of sulphurous acid. If the air, or oxygen, in which they are burned be perfectly dry, no other acid is produced; but if moisture be present, sulphuric as well as sulphurous acid is generated. These two acids differ in the proportions of oxygen which enter into their composition, sulphurous acid

containing six and sulphuric acid twenty-four parts of oxygen.

The most important sulphates to the agriculturist, are, the sulphate of ammonia, a powerful manure for crops requiring much nitrogen; sulphate of lime, which produces on certain soils luxuriant crops of clover, lucern and other plants, of which it forms a constituent; and sulphate of magnesia, the well-known medicine, Epsom salts, which may be used with advantage as a manure, in a manner which will be described hereafter. The sulphate of the protoxide of iron may also be mentioned on account of the injurious effects which it exerts on vegetation when present in the soil, and the necessity of decomposing it by means of lime. Its presence may be known by the rusty red deposit formed in water which drains from the soil.

Phosphorus.

This is a substance which may be seen in almost every chemist's shop, and is well known from its property of taking fire by slight friction, or even by exposure to the air. Hence the necessity of keeping it in close vessels filled with water. Its combinations with oxygen produce the phosphorous and phosphoric acids. Phosphoric acid is a constituent of all fertile soils; and phosphates enter into the composition of all plants. The phosphates of lime and magnesia are most abundant in the seeds, particularly of corn, and are contained in the bones, and liquid and solid excrements of men and animals. From some experiments made by Sprengel, phosphate of iron in the soil appears to be the cause of the red rust by which the straw of wheat and barley is affected.

Carbon.

When wood is exposed to a red heat in close vessels, so as to exclude the air, it is converted into charcoal, a hard, light and brittle substance, insoluble in water, little affected by any of the acids or alkalies, little subject to change from exposure to moisture, and supporting the most intense heat which chemists have been able to apply, without undergoing alteration, provided only that air be excluded.

When set on fire, in contact with air, charcoal burns away, leaving a small quantity of ashes, (about one fiftieth of its weight,) which consist of potassa, earthy salts, and metallic oxides. These are impurities foreign to the real matter of charcoal, which is the carbon of chemists, and which, strange as it may appear, is identical in properties with the diamond.

Charcoal, fresh made and perfectly dry, has the property of absorbing gases in large quantities, and giving them out again when immersed in water. It is probably to this quality that it owes its efficacy in removing the taint from meat in an incipient state of putrefaction, and of sweetening putrid water. It is to the same property of absorbing gases, particularly carbonic acid, that its capability of affording nutriment to plants may be ascribed. When charcoal is burned in oxygen the combustion is attended with intense heat and light: the carbon and oxygen combine, and carbonic acid is the product.

Carbonic acid is likewise the result of the combustion of charcoal in atmospheric air, with the oxygen of which it combines.

Carbonic Acid.

The decomposition of wood and vegetable fibre may be regarded as a slow species of combustion, during which the combination of its carbon with oxygen is effected, producing carbonic acid; and it will be shewn hereafter that plants derive their carbon from the carbonic acid of the atmosphere, which they have the power of decomposing, and that they retain the carbon, and restore the oxygen to the atmosphere. Animal bodies also contain carbon; and carbonic acid is one of the products of their decomposition. Carbonic acid may be easily procured by submitting carbonate of lime (common limestone, chalk or marble) to the action of an acid which has a greater affinity for the lime than carbonic acid has. If the beak of the retort in which the carbonic acid is generated, be plunged into a vessel of lime water, it will combine with the lime dissolved in the water, and reproduce carbonate of lime, which will be disseminated through the water in white clouds, and finally settle to the bottom of the vessel. The crust, like thin ice, which forms on the surface of a vessel of lime water exposed to the air, consists of carbonate of lime, formed by the lime combining with carbonic acid, derived from the atmosphere, which always contains a small portion of that gas.

This property of producing a precipitate in lime water affords a test by which the presence of carbonic acid may be detected. Carbonic acid is heavier than atmospheric air, and may be poured from one vessel to another like water. This property causes it to accumulate at the bottom of wells and caverns, when exhaled from the earth, from which it issues in vast

quantities, particularly in the vicinity of volcanos. If a burning taper be plunged into a jar of carbonic acid, it will be extinguished. Carbonic acid likewise produces death when received into the lungs; hence the fatal effects which have resulted from burning charcoal in close apartments, or from descending into wells and drains in which carbonic acid has accumulated, or into vats in which the process of fermentation has been conducted. It is usual, before descending into such situations, to take the precaution of first letting down a lighted candle, to ascertain the presence of carbonic acid, commonly called "foul air," or choke damp; but this test is not always to be relied on, for when sufficiently diluted with atmospheric air to prevent its extinguishing the flame it is still fatal to animal life. The best mode of removing the carbonic acid from such situations, is to throw down thirty or forty pails full of water, by which an agitation is produced in the column of air, causing the heavy carbonic acid that lies at the bottom to rise and be carried off. A quantity of quick lime added to the water will more effectually remove the noxious gas, by entering into combination with it.

During the process of lime-burning, carbonate of lime is decomposed by means of heat and carbonic acid driven off. Hence the fatal effects which have resulted from persons incautiously lying down to sleep near lime kilns.

The refreshing qualities of spring water arise from the presence of carbonic acid, of which water absorbs spontaneously its own bulk, and may be made by pressure to take up much larger quantities. Water thus treated sparkles and effervesces under the ordinary pressure of the atmosphere, and is the well-known

beverage named soda water. Water impregnated with carbonic acid is deprived of it by the process of boiling or freezing. Carbonic acid is also generated during the process of fermentation; its presence imparts their briskness to bottled beer, cyder, and champagne, and occasions the lightness or sponginess of bread.

There is another compound of carbon with oxygen, which contains a smaller proportion of oxygen than carbonic acid, and is known by the name of carbonic oxide, it extinguishes flame and is as fatal if respired as carbonic acid, but differs from that gas in many of its properties. It is combustible, burning with a blue flame, is not acid, and is not absorbed by lime water.

The combustibility of the diamond, suspected by Newton, was proved by Lavoisier, who effected its combustion in a vessel of oxygen by means of the rays of the sun, concentrated by a powerful lens. The product of the combustion was carbonic acid, and the same results have since been obtained by many other eminent chemists. Like carbon also, the diamond when heated, in contact with iron, converts it into steel. The identity of carbon and the diamond is thus completely established.

Compounds of Carbon and Hydrogen.

Carbon and hydrogen unite in several different proportions. The fire-damp, which occasions such destructive explosions in collieries, is carburetted hydrogen; the gas with which our streets are lighted consists of bicarburetted hydrogen, mixed with carburetted hydrogen, hydrogen, and carbonic oxide. This gas is procured for economical purposes, by distilling coal out of contact with the air in iron retorts, and collecting the gaseous products in a large vessel inverted in

water, called a gasometer, which is merely the pneumatic trough on a large scale. The other products of this distillation are tar and an ammoniacal liquor which are condensed by passing them through pipes immersed in cold water. The relative quantity of these different products obtained depends much upon the nature of the coal, and the degree of heat employed, a slow heat giving much tar and little gas; and a quick heat producing much gas of a better quality and but little tar. Gas nearly similar is also prepared for illuminating purposes by the decomposition of oil and resin.

Coal is mineralized wood; and if wood or other vegetable matter in general be exposed to heat in close vessels, so as to exclude the air, nearly the same products will be obtained. It will be resolved into its ultimate elements, carbon, hydrogen, oxygen and nitrogen, the last in the smallest quantity; and the union of these elements during this process, which is called destructive distillation, produces hydrogen, carburetted and bicarburetted hydrogen, carbonic oxide and carbonic acid.

The experiment may very easily be made on a small scale with a tobacco-pipe—(one of those long Dutch pipes with a large bowl answers best)—filled with the sawdust of green wood; let the bowl be then stopped with clay, and after the clay is well dried, let it be inserted in the fire; as the sawdust becomes heated, the water which forms the principal part of its juices, will come over in the form of vapour, and will drop from the end of the pipe if it is kept cool; as the process proceeds this water will be found to have an acid reaction on test paper, from the presence of acetic acid. Soon afterwards a gas will issue from the pipe, which will be inflamed on the application of a lighted taper,

and will burn with a light yellow flame; or it may be collected in a flaccid and moist bladder from which the air has been expelled by squeezing it, or in a small tube closed at one end, filled with water and inverted in another vessel of water, so as to form a small pneumatic apparatus.

Compounds of Carbon and Iron.

Carbon and iron unite in various proportions. The three most important carburets of iron are *graphite* (commonly called plumbago and black lead), *cast-iron* and *steel*.

Graphite contains from 4 to 10 per cent. of carbon; it occurs as a natural production, and may be formed artificially by exposing iron with excess of charcoal to a long continued heat. Like carbon, graphite remains unaltered by long exposure to heat in close vessels, but heated in contact with the air, or oxygen, its carbon is converted into carbonic acid, and oxide of iron remains. Its chief use is for making black lead pencils and crucibles, for preserving iron from rust, and diminishing the friction of machinery.

Cast-iron is iron as extracted from its ore in the process of smelting; it contains from 3 to 5 per cent. of carbon, and is contaminated by various impurities, such as undecomposed fragments of ore and several earthy matters. Cast-iron is by no means uniform in its quality, and is particularly distinguished into two kinds, the *white* and the *gray*, which appear to differ not so much in the proportion of carbon contained in them, as in the mode of its combination.

White cast-iron is very hard and brittle; the gray is softer and more tenacious. The white may be converted into the gray by being slowly cooled after ex-

posure to a strong heat, and the gray may be changed into white cast iron by the opposite process, namely, by being heated and rapidly cooled.

Wrought iron is the fused metal rendered malleable by being deprived of its carbon. This is effected by exposing it to a strong heat, while a current of air plays upon its surface, by which means its carbon is oxidized. The iron at length loses its fusibility, and becomes solid; after which its particles are approximated, and its tenacity increased by the operations of rolling and hammering.

Steel is prepared from malleable iron by the process called *cementation*. This consists in exposing the purest iron and powdered charcoal, arranged in alternate layers, to a red heat for several days, access of atmospheric air being carefully excluded. The iron thus gradually combines with from 1.3 to 1.75 per cent. of carbon, and becomes blistered on the surface. Steel is also formed by exposing heated iron to a current of coal gas, when carburetted hydrogen is decomposed, and its carbon enters into combination with the iron. Steel is harder, more compact, and more sonorous than iron, and susceptible of a higher polish, though less ductile and malleable. It is capable of fusion, but less so than cast iron. Cast steel is of a more uniform texture and closer grain than common steel.

Wrought and cast iron and steel are substances of such importance in agricultural operations that their names are familiar to every one, though few are aware in what their difference consists. I have therefore thought that this brief notice of them would not be uninteresting, or misplaced; though, had it been my intention to describe the metals, they would have been more appropriately mentioned under the head of iron.

Silicon.

When rock crystal or common flint, after exposure to a strong heat, is thrown while red-hot into water, it may be reduced to a light white powder, which feels gritty to the touch, and is destitute of taste or odour. This is silicic acid, called also silica, and siliceous earth. It may be procured in sufficient purity for most purposes by treating transparent rock crystal in the manner above described; fusing the powder thus obtained in a crucible with dry carbonate of potassa, dissolving the fused mass when cold in dilute muriatic acid, and filtering and evaporating the solution to dryness. After washing the product of evaporation first with dilute muriatic acid, and then frequently with water, dry it, and pure silicic acid will be obtained. Pure silicic acid is infusible by itself, except before a stream of the mixed hydrogen and oxygen gases, known as the oxy-hydrogen blowpipe; it is insoluble in water, except when in the nascent state, that is, when in the act of liberation from some of its compounds, and then water dissolves it in large quantities. On evaporating the solution a bulky gelatinous hydrate separates, which cannot be deprived of all its water except by a red heat.

When Sir Humphrey Davy was conducting his experiments for the decomposition of the earths and alkalies which have been already noticed, and will be hereafter more particularly described, he proved that silicic acid consisted of a combustible base united with oxygen; for on bringing pure silicic acid heated to whiteness in contact with the vapour of potassium, a silicate of potassa was formed, through which were diffused brown particles resembling plumbago. To

these, on the supposition of their being metallic, he gave the name of silicium. Seeing however that it was destitute of the metallic lustre, and was a non-conductor of electricity—thus wanting two of the most characteristic properties of a metal—Dr Thomson classed it among the non-metallic solids under the name of silicon. And the subsequent researches of Berzelius may be regarded as decidedly in favour of these views.

Silica.—The acid properties of silicic acid are, it is true, very feeble. It has no action on test-papers, but, aided by the action of heat, it enters into combination with the alkalies, and displaces carbonic acid with effervescence from their carbonates. In its combination also with the earths and metallic oxides it performs the part of an acid to which they act as bases. These compounds are known in modern chemistry by the name of silicates.

Silicates.—The properties of the silicates of the alkalies vary with the proportions of the ingredients employed. Glass is a silicate of potassa, composed of three parts silex and one part of alkali. The various appearances and properties of different kinds of glass arise from differences in the purity of the materials employed. Bottle-glass is made from coarse kelp or pearl-ash and river-sand, which contains sufficient iron to impart to it its olive-green colour. Window-glass is made from purer alkali and sand; plate-glass from the purest form of silex and alkali. A considerable quantity of red lead, or litharge, is added to flint-glass. Peroxide of manganese is sometimes used to oxidise the carbonaceous matters contained in the materials employed.

When the proportions are reversed, and one part

of silicic acid is fused with three parts of carbonate of potassa, the result is a silicate of potassa soluble in water. By these means siliceous minerals are brought into a state of solution for the purpose of analysis, and of preparing pure silicic acid according to the process described in the last paragraph.

Silicic acid constitutes almost the whole of the minerals known by the name of flint and quartz, or rock-crystal; it is an abundant constituent of many rocks, and forms the chief portion of all sandy soils.

Presence of Silica in Plants.

Silicic acid enters largely into the composition of many plants, particularly the grass tribe. It is most abundant in the glossy surface of canes and reeds and other grasses, and also in the husk of their seeds. Oats contain a larger proportion of silica than any other kind of corn. If two canes be rubbed together in the dark, they emit light like that obtained by the friction of quartz pebbles. Lumps of a substance called *tabasheer*, containing 70 per cent. of pure silicic acid, and very much resembling the mineral called opal, is found in the stem of the bamboo near the joints. It is also deposited on the stems of some species of the equisetum, particularly that called Dutch reed (*equisetum hyemale*), which from this cause derives its utility as a polishing material. In the ashes of a burnt hay or corn-rick semi-vitreous masses of silicate of potassa may be found, derived from the silica and potassa abounding in the straw.

BASES OF THE ALKALIES.

Potassium.

Chemists had failed in all their attempts to decompose the alkalies, soda and potassa, &c., until the year 1807, when Sir Humphrey Davy by exposing them to the action of a powerful voltaic battery proved them to be compounds of oxygen with certain peculiar metals, to which he gave the name of potassium and sodium. By the same means he shortly afterwards succeeded in decomposing the earths, lime, alumina, &c., till then considered elementary bodies, and he demonstrated that they likewise were metallic oxides.

Potassium has since been obtained by other processes, but they are all too difficult for any but an experienced chemist. Those, however, who wish to examine its properties, may purchase it of the operative chemist at the rate of about a penny the grain. It is a metal, in colour and lustre much resembling mercury, solid at the ordinary temperature of the atmosphere, and so soft that it may be moulded with the fingers. It is lighter than water. One of its most remarkable properties is its strong affinity for oxygen, which is so great that it can only be preserved in the metallic state in glass tubes hermetically sealed or immersed in liquids, such as naphtha, of which oxygen is not a component. Heated in contact with air it takes fire and burns with a purple flame. When thrown into water it swims on the surface, abstracting oxygen from the water with evolution of such intense heat, that the potassium is inflamed and burns with a brilliant light; and the water in which the oxide of potassium is dissolved acquires alkaline properties.

Potassa.—There are two oxides of potassium: the protoxide, formed when potassium is thrown into water or exposed at the common temperature to air or oxygen; and the peroxide, the result of the combustion of potassium in air or oxygen: it contains three times as much oxygen as the protoxide. Caustic potassa, a hydrate of the protoxide, or combination of the protoxide with water, is prepared from the pearl-ash of commerce. It is highly deliquescent, caustic, destroying all animal textures, of an acrid taste, and highly alkaline in its properties, converting vegetable blues, except litmus, to green, neutralizing the strongest acids, and changing vegetable yellows to brown. Potassa combined with certain acids is found in various proportions in the ashes of most plants.

Potassa is also a constituent of the mineral called felspar, one of the ingredients of granite; and as clay is formed of decomposed felspar, clayey soils abound in potassa. It is this circumstance which renders them so favourable for the cultivation of wheat, which contains more potassa than either barley or oats; and hence the value of salts of potassa on light lands, by supplying their deficiency in that substance, and of wood-ashes, which contain potassa.

Sodium.

Is a metal similar in appearance to potassium. It oxidizes by exposure to the atmosphere, though less rapidly than potassium, and, like it, must be preserved in naphtha. When thrown into cold water it effervesces violently, but does not inflame (except in hot water), and gradually disappears, converting the water into a solution of soda.

Soda.—There are two oxides of soda formed under the same circumstances as those which give rise to the protoxide and peroxide of potassa. The caustic soda of chemists is the protoxide, in combination with water, and is analogous in its properties to proto-hydrate of potassa. Salts of soda exist but sparingly in the ashes of land-plants; but they abound in those of sea-weeds, and of plants that grow near the sea, or within the influence of brine springs. In those species of plants, however, which abound in salts of soda, when growing in such situations, the soda is replaced by potassa when they are grown in situations beyond the influence of the sea. Soda is largely prepared from the kelp and barilla of commerce, which are the ashes of burnt sea-weeds. The former is manufactured on the coasts of Ireland and the western islands of Scotland, the latter on the shores of the Mediterranean. Soda is also prepared on a large scale by decomposing common salt or chloride of sodium by means of sulphuric acid. The alkalies have the property, when combined with oil or fat, of rendering them soluble in water, and large quantities of them are consumed in the manufacture of soap.

Calcium.

In decomposing the earths with the galvanic battery Davy encountered greater difficulties, and was compelled to have recourse to a more complicated process, than in the case of the alkalies. By these means he succeeded in obtaining the metallic base of lime, though in such small quantities that its properties are but little known. It is a white metal of moderate lustre, which on being heated in contact

with oxygen takes fire and forms an oxide, which is lime.

Lime.—There are two oxides of this metal; the protoxide, known by the name of lime or quick-lime, is obtained from chalk and limestone by the well-known process of lime-burning. For chemical purposes, where great purity is required, it is prepared from Carrara marble, or that clear variety of crystallized carbonate of lime known by the name of Iceland spar.

Lime or protoxide of calcium is a brittle, white, earthy solid; it is one of the most infusible of the earths, yielding with difficulty to the oxy-hydrogen blowpipe. Water poured upon lime enters into combination with it, accompanied by a great increase of temperature. This process is the common operation of *slaking* lime; and the hydrate of lime thus produced is *slaked lime*.

The hydrate is soluble in water, and has an acrid taste, neither of which properties are possessed by pure lime. It is more soluble in cold than in hot water.

Lime-water, which has before been spoken of as a test of the presence of carbonic acid, is prepared by agitating quick-lime repeatedly in water, and setting it aside in a well-closed bottle, till the undissolved parts have subsided. This solution has a strong alkaline reaction on vegetable colours.

Lime is a most abundant earth in nature. It has been estimated that carbonate of lime constitutes one eighth of the entire crust of the globe. Though the carbonate is sparingly soluble in water, it is dissolved by carbonic acid in excess. The spring water therefore of calcareous districts always contains carbonate of lime, which is deposited when the excess of carbonic acid is expelled by boiling. The crust, or fur formed

in tea-kettles is carbonate of lime, deposited from this cause. Spring water also frequently contains the sulphate and hydrochlorate, as well as the carbonate of lime.

Lime is the earth most generally present in the ashes of plants, particularly in the form of the carbonate. In the stems of some species of the *charæ*, a family of aquatics, carbonate of lime is so largely deposited that they are invested with a stony covering.

Magnesium.

The carbonate and sulphate of magnesia, the latter generally known as Epsom salts, are extensively used in medicine. Oxide of magnesium, or magnesia, is obtained by exposing the carbonate to a strong red heat, by which its carbonic acid is driven off. Davy proved the existence of magnesium as the base of this earth, and Bussy and Liebig have since obtained it by the action of the vapour of potassium on chloride of magnesium. The metal thus obtained has a brilliant metallic lustre, and in colour resembles silver. It oxidizes slightly in moist air, not at all in dry air, and may be boiled in water without being decomposed. Magnesia is the result of the vivid combustion which takes place when it is heated in air or oxygen gas.

Magnesia.—This is the only known oxide of the metal. Like lime and alumina it emits a brilliant white phosphorescent light when strongly ignited. It is a light, white, friable powder, tasteless and inodorous when pure; it combines with water like lime, though with a less powerful affinity. The hydrate is sparingly soluble in water; the solution does not change the colour of vegetable blues; but pure magnesia laid upon moist turmeric paper produces a brown stain.

Magnesia was formerly obtained from sea-water. After being sufficiently boiled down, if it be mixed with pearl-ash a white powder subsides, which, after being thoroughly washed, is carbonate of magnesia, which has derived its carbonic acid from the carbonated alkali employed. It is now generally prepared from a mineral called magnesian limestone, consisting of the carbonates of lime and magnesia.

Sulphate of magnesia is made by digesting this limestone in sulphuric acid. The mineral called serpentine, which contains from 37 to 38 per cent. of magnesia, and not more than 10 per cent. of lime, is found to answer better for this purpose, as occasioning less waste of sulphuric acid by conversion into sulphate of lime.

The stone with which the new houses of parliament are being built is magnesian limestone, from the county of Durham. It contains about 30 per cent. of lime, 21 of magnesia, 47 carbonic acid, and 1 oxide of iron. Some varieties of magnesian limestone have the property of forming a cement which sets under water. As a manure it requires to be applied in smaller quantities than the lime prepared from common limestone.

Phosphate of magnesia is found in the ashes of certain plants, particularly the seeds.

Aluminum.

Davy inferred that alumina was a compound of oxygen with a metallic body, from the effects produced when pure alumina heated to whiteness was brought into contact with the vapour of potassium; and the metal has since been procured in the state of a gray powder, very similar to that of platinum.

It requires for its fusion a higher temperature than that at which cast iron melts. Water has but little action on it at common temperatures; but when heated to the boiling point it produces slight oxidation. When exposed to a red heat in oxygen it burns with a vivid light, and the result is white aluminous earth of considerable hardness.

Alumina.—There is but one known oxide of this metal. With respect to its composition, there is some difference of opinion among chemists. It is generally supposed however that aluminum combines in the proportion of two equivalents of the metal to three equivalents of oxygen. Alumina will therefore be a sesquioxide containing one equivalent of aluminum to one equivalent and a half of oxygen. Pure alumina is tasteless and inodorous, but exhales a smell known as the "earthy" when breathed upon. This arises from the presence of ammonia which it has absorbed. It is quite insoluble in water, but combines with it with great avidity, and will not part with it after being moistened except at a full white heat. It is this affinity for water which causes it to adhere to the tongue, and to form, when mixed with a sufficient quantity of water, a tenacious mass capable of being moulded into any form; a property which renders it of so much utility in the manufacture of pottery. Alumina is one of the most abundant earths in nature, being an important ingredient of the granitic and slate rocks, and constituting the bulk of all clayey soils, which result from the decomposition of those rocks. But though clay, or hydrate of alumina, is so abundant, it rarely occurs in a state of purity, being mixed with siliceous and calcareous earth and with oxide of iron, from the last of which burnt

clay derives its red colour. Marl is a mixture of clay and calcareous matter; loam is a mixture of clay and sand.

Though the most common form of alumina is that of coarse, soft, and shapeless clay, yet in its crystalline state it constitutes the ruby and the sapphire, which next to the diamond are two of the hardest and most valuable of precious stones. Corundum, or emery, which is so hard as to be used for the polishing of gems, contains about 80 per cent. of alumina. These facts will appear less extraordinary after the identity which chemists have established between the diamond and carbon.

Alumina appears to act both as an acid and a base. In the minerals above mentioned it is seen under the former character, and they are therefore called aluminates. It constitutes however the base of some salts. Sulphuric acid forms with it sulphate of alumina, and with alumina and potassa the well-known salt called alum, a double sulphate of alumina and potassa. It is manufactured in large quantities at Whitby in Yorkshire from alum-slate, an argillaceous shale highly charged with sulphuret of iron. On roasting this its sulphur is converted into sulphuric acid, which unites with the alumina and potassa present in the shale. This salt is separated from the mass by lixiviation, or washing with water, and purified from the iron mixed with it by repeated crystallization.

From this salt alumina derives its name. Alumina may be prepared from alum by the following process: Alum proved to be free from iron by dissolving in a solution of pure potassa, without residue or without the presence of brown flocks, is to be dissolved in four or five times its weight of boiling water;

a slight excess of carbonate of potassa is to be added, and after digesting for a few minutes, the bulky hydrate is to be collected on a filter, and well washed with hot distilled water. The alumina however is so retentive of the alkali that it cannot be separated by the action of water. The precipitate must therefore be re-dissolved in dilute hydrochloric acid, and precipitated by pure ammonia or its carbonate. This precipitate, after exposure to a white heat, will be pure anhydrous alumina, or alumina uncombined with water.

SECTION IV.

PROXIMATE CONSTITUENTS OF ORGANIC BODIES.

Proximate constituents of plants—compounds containing oxygen and hydrogen in the proportion in which they form water—woody fibre—gum—starch—sugar—compounds in which the proportion of oxygen is greater than in water—vegetable acids—compounds containing hydrogen but no oxygen—resins—volatile oils—wax—camphor—balsams—caoutchouc—other proximate constituents of plants—vegetable alkalies—proximate animal constituents—bones—cartilage and gelatine—muscular fibre—albumen—ozmazome.

Plants.

NOTWITHSTANDING the immense variety of organic bodies which constitute the animal and vegetable kingdoms, they are composed for the most part of four elementary substances, oxygen, hydrogen, carbon, and nitrogen. The three former are the principal constitu-

ents of plants, which contain nitrogen in but small proportions, while that element and carbon enter most extensively into the composition of animals. The vegetable kingdom is the primary source whence man and animals derive their nutriment. Inorganic substances, on the other hand, supply the means of growth and nourishment to plants.

Carbon enters into the composition of all plants, and of all their parts and organs.

1. The greater portion of every vegetable consists of carbon united with oxygen and hydrogen in the proportion in which they combine to form water; such are woody fibre, gum, and sugar.

2. In other compounds containing carbon, *oxygen and hydrogen are present, but the proportion is greater than that in which they form water.* Most of the organic acids are of this class.

3. The volatile and fixed oils, wax, and resins, contain *carbon and hydrogen, but no oxygen.*

The juices of all vegetables contain *organic acids* combined with *inorganic bases* and *metallic oxides.* These bases exist in every plant and may be detected in their ashes after incineration. They appear in the ashes in the form of carbonates; for all salts of organic acids yield carbonates by incineration; and when on the addition of an acid to the ashes of a plant effervescence takes place, it may be regarded as a proof that its alkaline and earthy bases were united in the living plant with organic acids.

Nitrogen exists in every part of vegetable structure, is found in the largest proportion in vegetable *albumen*

and *gluten*; and is a constituent of acids, of the indifferent substances of plants, and of those peculiar vegetable compounds which combine like metallic oxides with acids, and are known as *organic bases*. It forms only a small part of plant, but is never entirely absent from them; and when it does not enter into the composition of a particular organ, is always found in the juices which pervade it.

Vegetable Compounds of Carbon with Oxygen and Hydrogen in the proportion in which they form water.

Lignin or vegetable fibre.—When a vegetable of any kind is boiled for a length of time in water, the water being repeatedly changed, its appearance becomes considerably altered, its taste and colour and medical properties, if it had any, are in general entirely destroyed, and nothing remains but a mass of fibre, which resembles wood in its properties. This is the woody fibre which constitutes the basis of all vegetable structures, and amounts to from 96 to 98 per cent. in the different kinds of timber, which are all composed of the same elements, their different degrees of hardness originating in a difference of cohesion among their particles.

Lignin may be converted by the action of sulphuric acid into a substance resembling gum arabic, and into sugar. The former substance is produced when sawdust is well mixed with strong sulphuric acid. As soon as the mixture has grown clear chalk is to be added, and the mixture strained and evaporated to dryness. The result is a tasteless yellow and transparent substance, possessing most of the properties of gum, which will presently be described. If this gum

be again heated with sulphuric acid, it will be converted into a crystallizable sugar like cane-sugar.

The chief constituent of hemp is lignin; and a piece of hempen cloth may thus be converted into sugar by the action of sulphuric acid.

Gum.—Pure gums—gum arabic for instance—are tasteless, perfectly *soluble in water*, the solution viscid, *insoluble in spirits of wine*, capable of cementing broken fragments, and of forming a varnish.

Gluten and starch.—If the flour of wheat be made into dough, and kneaded under water, it will separate into two parts, a glutinous gray elastic substance, somewhat resembling fresh Indian rubber, will remain in the hand; this is gluten; and the water will become white with a floating powder. This, which is to be allowed to settle and to be collected, is starch. Gluten contains about 16 per cent. of nitrogen; it is one of the most nutritive of vegetable substances, and the superior nutritious powers of wheat arise from the larger proportion of gluten contained in it. An increase of animal manure increases, as was before stated, the amount of gluten, and the wheat of the southern countries of Europe contains more gluten than that of the north. It is this abundance of gluten which causes Sicilian and Odessa flour to absorb more water than that of English, and consequently a sack of it produces from four to six loaves more. It is to the gluten that bread owes its lightness, the carbonic acid disengaged from the yeast and detained by the tenacious gluten causes the dough to expand or rise; and the absence of gluten from the flour of wheat badly harvested renders necessary the mixture of Odessa flour in order to cause the loaf to "stand up," as bakers term it, in the oven. Flour abounding in

gluten is of a browner colour, though more nutritious than that which abounds in starch, which causes whiteness of colour.

Starch is obtained from different kinds of grain, from potatoes, and from other vegetable substances. *Indian arrowroot*, tapioca, and sago, are all varieties of starch. Starch is insoluble in cold water and alcohol, but very soluble in hot water. Its presence may be known by the azure blue colour which it produces with a solution of iodine.

The starch both of grain and potatoes is convertible into sugar by the action of sulphuric acid. The two substances are to be boiled together for a long time, and some chalk is then to be added. The liquid after being strained is to be evaporated, when lumps of sugar will crystallize, the weight of which will be about one-tenth greater than that of the starch employed. Sugar thus formed may be distilled into alcohol, or spirits of wine. It is not however equal in sweetness to that of the cane.

Sugar.—Other plants besides the sugar-cane produce sugar. In America it is made from the juice of a species of maple; in France it is extensively manufactured from beet-root and from grapes. One hundred gallons of the juice of the cane produces 108 lbs. of sugar, of which 112 lbs. yield 61 lbs. of refined sugar; the remainder being bastards and molasses, with about 5 lbs. of loss. When the juice is sufficiently purified and evaporated, it crystallizes in small grains. Candied sugar is formed by dissolving either hard or soft sugar in a small quantity of water, and exposing it to cold, when it forms into regular crystals. Grape sugar is also crystallizable in groups of grains, but not into regular crystals.

Vegetable Compounds of Carbon with Hydrogen and Oxygen, in which Oxygen is present in larger proportion than in water.

Vegetable Acids.

The vegetable acids have been already mentioned as belonging to this class. Some of them exist ready formed in plants; others are obtained by the action of heat on those acids, or by the action of nitric acid upon certain vegetable substances. The former are called *educts*, the two latter *products*.

The following are some of the most important organic acids which exist ready formed in the juices of plants.

Citric acid is obtained from the juice of lemons. This is first saturated with powdered chalk to form citrate of lime. This, after being well washed to free it from the mucilage with which the acid was combined in the juice, is decomposed by heating it with dilute sulphuric acid, which forms with the lime an insoluble sulphate. The acid liquor is then evaporated to a certain state, and on cooling crystals of acetic acid are formed.

Sorbic, called also *malic acid*, is obtained from the juice of the berries of the service tree (*sorbus aucuparia*), and of the apple.

Tartaric acid is made from cream of tartar, a crust deposited on the under side of wooden vessels in which wine is long kept.

Oxalic acid.—This acid, which consists of carbon twelve parts or two doses, and oxygen twenty-four parts or three doses, was originally obtained from the juice of wood-sorrel (*oxalis acetosella*), whence its

name. It is now prepared in large quantities by the action of nitric acid upon sugar; and is therefore sometimes called, though improperly, acid of sugar. In the form of the crystals oxalic acid so much resembles sulphate of soda, or Epsom salts, that it has frequently been swallowed by mistake for that medicine. The remedy in such cases is to cause the patient to drink copious draughts of water in which whitening (*powdered chalk*) is diffused; when the carbonate of lime neutralizes the acid, forming with it oxalate of lime.

Oxalate of ammonia is used as a test for the presence of lime. The oxalate of lime, which is formed on the addition of that salt to water holding lime in solution, produces a milky appearance, and thus lime may be detected in the water of most springs.

Gallic acid is procured from powdered gall-nuts, which are heated in a glass retort, until crystals form in its neck. These consist of gallic acid. Its acid properties are, however, but very feeble. Chemists are not agreed whether in its pure state it reddens litmus paper. Its taste is rough and bitter, rather than sour, but it neutralizes alkalies, and expels carbonic acid from their carbonates. It changes the colour of solutions of salts of iron to black, and is therefore used in the formation of ink.

These are the most important vegetable acids, but there are a number of others of minor consequence; such as

Benzoic acid, obtained from a resin called benzoen. On exposing this to the action of heat in a retort, the acid sublimes and condenses on the cool part of the glass, in the form of brilliant white and downy crystals, of a fragrant odour, and strong aro-

matic taste. Their solution reddens litmus paper, and neutralizes alkalies. They therefore possess acid properties.

Moroxylic acid obtained from the bark of the mulberry.

Ulmic acid, from that of the elm.

Kinic acid, from the Cinchona tree which produces the Peruvian bark.

The *silvic* and *pinic* are acids obtained from turpentine.

Mechonic acid, from poppy-heads.

Pectinic acid, from carrots and other vegetables; with many others which it is needless to enumerate.

Acids generated by the action of heat on some of the above-mentioned acids.

The citric, tartaric, and other vegetable acids, are decomposed by distillation at a high temperature, and new acids are formed, distinguished by peculiar properties. These have the word *pyro* prefixed to the name of the acid from which they are derived. Thus we have pyro-citric, pyro-tartaric, and pyro-sorbic acids, all differing in their properties from the acids from which they were formed. Others are generated by the action of heat which have simple names, because they are not known to exist in a previous acid state; such are

Succinic acid, distilled from amber, a vegetable resin found in a fossil state.

Ricinic acid, }
Elaiodic acid, } two acids distilled from castor oil.

Croconic acid, formed by heating together carbon and potash.

Acids generated by the action of Nitric Acid on vegetable substances.

Carbazotic acid, the product of indigo heated in strong nitric acid, is a solution which on cooling deposits transparent yellow crystals which have a bitter taste, redden vegetable blues, and form crystallizable salts with alkalies and earths.

Indic acid.—If indigo be boiled in nitric acid much diluted with water, water being continually added to prevent concentration, the yellow solution thus produced yields, on evaporation, white silky crystals having an acid bitter taste. These consist of Indic acid, which by the action of strong nitric acid is converted into the carbazotic.

Aloetic acid is formed by the action of nitric acid on aloes. It consists of carbazotic acid combined with a peculiar resinous substance. By means of mordaunts it is capable of communicating a variety of beautiful dyes to silk, leather, and wool.

Saclactic acid is obtained by the action of nitric acid on the sugar of milk.

Mucic acid by treating gum arabic with nitric acid. These two are considered to be identical.

Camphoric acid is obtained by the same means from camphor, and *suberic* acid from cork.

Compounds containing Carbon and Hydrogen, but no Oxygen.

To this class belong the resins and the fixed and volatile vegetable oils, also wax and camphor.

Resins are generally transparent, always coloured, their colour becoming darker by age. They have a

pungent taste and a strong odour, are insoluble in water, but soluble in alcohol; water added to the solution causes the resin to separate in the form of a floating white powder. They melt with heat, and harden again on cooling; if much heated they take fire, and burn with considerable flame and smoke. By distillation in close vessels an odoriferous oil comes over, and the resin which remains in the retort becomes harder, darker coloured, and nearly destitute of smell. These oils being supposed to contain the essence, or principal medical virtues of the resins—some of which are much used in medicine—are called *essential* oils; and from their speedily evaporating or flying off when exposed to the air, they are also called *volatile* oils.

The well-known substance turpentine is a good example of a resin. It abounds in the juices of all the fir tribe, exuding from wounds in the bark and from broken branches as a viscid fluid, which hardens by exposure to the air.

When turpentine is distilled, a thin colourless strong-smelling liquid, called essential oil or spirits of turpentine, comes over, and the resin which remains in the retort is white or dark-coloured, according to the mode in which the process is conducted. Myrrh and many other resins are spontaneous exudations from the leaves and branches of certain plants.

Essential oils.—Essential oils possess a variety of pungent tastes and powerful odours, dependent on the plant from which they were obtained. They occur in the bark, wood, leaves, flowers, and rind of the fruit; but are generally most abundant in the leaves and cortical parts, where they are lodged in small spherical and oblong cells. In some species of plants, the

myrtle tribe for instance, and the St John's w
pericum perforatum), the greater transparency of t
cells containing the essential oil causes the leaves when held up to the light to have a punctured appearance. The colour of essential oils is light when they are fresh made, but darkens with age. When shaken with water they appear to mix; but soon separate when at rest—the oil, according to its specific gravity, either floating on the surface or sinking to the bottom; it will be found however to have partially dissolved, and to have imparted to the water some of its taste and odour; and the water will have acquired these in a greater degree if left long in contact.

Fixed oils are those which, like olive-oil, oil of linseed, &c. are not volatile, have a mild taste, and do not dissolve in water. Few of them dissolve in alcohol. They do not take fire at so low a temperature as the volatile oils, and are not inflammable, like them, by affusion of nitric acid alone, but require it to be mixed with sulphuric acid. Fixed oils are rarely found in the leaves or cortical parts of plants, but are generally extracted from the seeds.

Wax and *camphor* are two well-known substances, compounds of carbon and hydrogen.

Wax constitutes the varnish on the leaves of many trees, and is found in the berries of a shrub called *vaccinium cerifera*, a good sized bush of which will yield a pound of wax. Bees have the faculty of converting the sugar of honey into wax by a process which it undergoes in their bodies. When confined in a room and fed on sugar they have been known to build a comb formed entirely of wax derived by these means from the sugar.

Camphor is a solid of a pungent taste and fra-

grant odour, volatile, sparingly soluble in water, readily soluble in alcohol, and in the oils both fixed and volatile. Like the resins it separates in flakes from its alcoholic solution on the addition of water. Camphor is deposited on the evaporation of certain fixed oils, particularly those extracted from the common lavender and its allied plants. The camphor of commerce is procured by sublimation from the *laurus camphora*.

Balsams are substances closely allied to resins; their distinctive character consists in yielding on distillation crystals of benzoic acid in addition to volatile oils. There are also some substances called resin-gums, which appear to possess properties intermediate in character between those of gums and resins. If digested in alcohol the resin is dissolved and the gum remains untouched; the reverse of this takes place when they are digested in water, while in a mixture of alcohol and water both the gum and resin are dissolved.

Caoutchouc, or Indian rubber, occurs in certain species of trees as a milky liquid, which exudes when the bark is wounded, and hardens by exposure to the air into an elastic solid, capable of being drawn into threads, and which melts at a strong heat. It is insoluble in water and alcohol, but soluble in oil of turpentine and other essential oils, and naphtha.

Other proximate Vegetable Constituents.

The vegetable acids which have been previously described are always found in plants associated with some base, either inorganic, as potash, soda, lime, &c.; or organic, as the vegetable alkalies. These are a class of bodies in which the peculiar qualities of the plants which contain them appear to reside. Most of

them possess decided alkaline properties; in others these properties are so feeble that they have received the name of *alkaloids*. Many of them are deadly poisons—some which are poisonous are most efficacious medicines when used in small doses. It will be sufficient to enumerate a few of them.

Quinina and *cinchonia* are derived from the bark of different species of the cinchonia-tree, or Peruvian bark, in which they occur in combination with kinic acid. They resemble each other in their bitter taste, and in their power of neutralizing acids, and forming with them crystallizable compounds. The principal difference is, that cinchonia crystallizes when uncombined with an acid, which quinina does not. Sulphate of quinina is much used in medicine as a substitute for the decoction of cinchonia bark.

Morphia and *narcotine* are two substances derived from opium (itself prepared from the juice of the poppy), the first alkaline, the second possessing neither the properties of an alkali nor an acid. The peculiar sedative qualities of opium are supposed to be due to the former, and its stimulating qualities to the latter.

Strychnia and *Brucia* are two powerful poisons, remarkable for producing tetanus or locked jaw. The latter is obtained from the bark of a tree (*Brucea antidysenterica*) common in Abyssinia; the powdered bark of which cured Bruce the traveller of a dysentery.

Digitalia, *hyoscyama*, *atropia*, *verateria*, are all substances of a powerfully poisonous nature, which are used in medicine in small quantities. Digitalia is obtained from the leaves of the foxglove, hyoscyama from the henbane, atropia from the deadly nightshade, and verateria from the hellebore.

The only importance of these vegetable alkalies and alkaloids in agricultural chemistry consists in the fact that in those plants to which they are peculiar, and to which they must be considered essential, they constitute the bases of organic salts, while in most of the plants cultivated by the farmer these organic salts have for their bases metallic oxides, which must therefore be regarded as of the same importance to those plants as the organic bases are to those in which they occur.

Tannin.—The tanning properties of oak-bark and other vegetable substances having an astringent bitter taste, are contained in a peculiar substance called tannin. In gall nuts it is associated with gallic acid. To obtain it in a separate form a complicated process is necessary. It is destitute of colour and odour, and has a rough and astringent bitter taste. A solution of it dropped into isinglass or glue (gelatine) forms a precipitate which is perfectly insoluble in water. To produce this effect the gelatine need not be in a state of solution, provided it be capable of being penetrated by the tannin. The art of tanning, or converting skins into leather, is nothing more than this process. Skins consist principally of gelatine, and on being immersed in an infusion of oak-bark its tannin combining with the gelatine renders it tough, hard, and insoluble, and prevents its putrefaction.

PROXIMATE CONSTITUENTS OF ANIMALS.

It has been already observed, that the chief distinction in the chemical composition of animal and vegetable matter consists in the much larger proportion of nitrogen contained in the former; carbon also is more abundant, and is less combustible than in vegetable matter.

The principal solids of the animal body are the bones and muscles, in which the animal strength resides, and which direct the motions—the tendons, in which muscles terminate, and by which they are united to the bones—the membranes, which line cavities—the skin or cutis, which envelopes the exterior surface of the body, and fat.

Bones.—Bone consists of

Gelatine and cartilage	32.17
Blood-vessels	1.13
Fluoride of calcium	2.00
Phosphate of lime	51.04
Carbonate of lime	11.30
Phosphate of magnesia	1.16
Soda, hydrochlorate of soda, and water	1.20
	100.00

Bones derive their firmness and tenacity from the gelatine and cartilage which they contain; the phosphates and carbonates, which constitute the chief portion of their structure, being naturally brittle and friable. By immersing bone for a long time in dilute muriatic acid, both the gelatine and the earthy salts are dissolved, and a mass of cartilage remains, retaining nearly the form of the original bone.

By boiling bones for a length of time in water the gelatine dissolves, and the water on cooling becomes a tremulous jelly. The remaining constituents are the earthy salts and the cartilage. The latter is most abundant in the bones of young animals. If the bones employed are those of a very young animal, had been broken very small, and boiled for a great length of

time, both the cartilage and gelatine would be dissolved, and the residue will consist wholly of the insoluble salts. In old animals the quantity of the cartilage diminishes, and has frequently a tendency to become bone. The disease called ossification is the conversion of cartilage into bone.

Gelatine.—Broth and soup consist of a weak solution of gelatine in water. When strong, it becomes on cooling stiff and tremulous, and constitutes *animal jelly*. If this be dissolved and boiled down till the water be nearly evaporated, it forms a hard, brittle, and transparent substance, known in the culinary art as *portable soup*, which is nothing more than glue prepared from edible materials. Ordinary *glue* is manufactured from the skin, horns, hoofs, bones, and other portions of animal bodies containing gelatine.

Muscular fibre.—The muscles consist of gelatine and fibrin, animal albumen, and osmazome. When muscle is washed repeatedly in water, its red colour changes to white, and it is seen to consist of a vast bundle of minute fibres, the substance of which has thence been named fibrin. The gelatine has been washed out of the muscle during the process, and is contained in the water. Flesh contains, on the average, 15.86 parts in 100 of fibrin, and this contains 18 per cent. of nitrogen. Strong acetic acid and heat convert fibrin into a jelly, which evolves nitrogen when dissolved in water. Strong sulphuric acid converts it into a white substance called *leucine*, which has the taste of boiled meat, and when heated gives out the smell of roasted meat. Nitric acid converts it into a crystallizable acid called the *nitroleucic*.

Albumen, which exists in many parts of the animal body, occurs nearly in a state of purity in the

white of egg. It is soluble in cold water, but coagulates when the solution is boiled. By continuing a moderate heat it may be converted into yellowish brilliant flakes, which are still soluble in water.

When a solution of corrosive sublimate (perchloride of mercury) is mixed with white of egg, a precipitate is immediately formed consisting of the protochloride (calomel), which is not poisonous. For this reason white of eggs is used to neutralize the poison of corrosive sublimate.

Osmazome is a kind of extractive matter which is obtained from raw muscle, by pressing it in successive quantities of water and separating it by evaporation, skimming off the albumen as it coagulates. The product of evaporation contains, beside osmazome, a small quantity of gelatine and salts. By dissolving the syrupy matter thus obtained in alcohol, and again evaporating, the osmazome is separated. It is soluble in water; the solution is not coagulated by heat, neither does it gelatinize on cooling. A strong solution of it has the acidulous taste perceptible in well-made soup. It is supposed that it communicates to soup and broth their peculiar taste and smell, and that they are the better in proportion to the quantity of osmazome which they contain. The name signifies odour of broth. The tendons, ligaments, membranes, and skin, consist principally of gelatine, and are almost wholly dissolved,—tendons wholly so, by continued boiling. The nails, hoofs, and horns, consist of gelatine and coagulated albumen. Nitrogen is a constituent of all these substances.

Fat and animal oils.—The fatty substances contained in animal bodies are either hard, as tallow; soft, as lard; or fluid, as oils. They are found to be

compounds of other proximate animal constituents. Fat and some fixed vegetable oils may be separated into two substances; the one, solid, brittle, transparent and inodorous, called *stearine;* the other, an oily fluid named *elaine*. Butter contains an oily fluid which has been named *butyrine*, soluble in alcohol, but not in water; sometimes white, sometimes yellow, and possessing the peculiar smell of butter. A peculiar oil, named *phocenine*, may be obtained from porpoise-oil, and another, named *hircine*, from the fat of sheep and deer, while spermaceti yields a crystallizable matter named *cetine*.

Soap is the well-known substance formed by boiling tallow or oil with a solution of soda or potash. The alkali produces a chemical transformation among the constituents of the fatty principles above mentioned, converting them into peculiar acids. The acids thus formed unite with the alkali which had been instrumental in generating them, and the salts mixed, or feebly combined, constitute soap.

To these acids various names have been given, derived from their properties, as the margaric, from its resemblance to pearl; or from the fatty substances from which they were derived, such as the stearic, oleic, butyric, hircic, and phocenic. Hard soap, which is made with tallow and soda, may therefore be regarded as the margarate, stearate, and oleate of soda; and soft soap, which is formed of oil and potash, as the margarate, stearate, and oleate of potash.

Besides the acids above mentioned, another, called the sebacic, and quite distinct from any of them, is formed by the distillation of fat or hog's lard in a retort with a brisk heat. It is crystallizable, and enters into various combinations.

PART II.

APPLICATION OF CHEMISTRY TO AGRICULTURE.

SECTION I.

THE CARBON OF PLANTS DERIVED FROM THE ATMOSPHERE.

Humus or mould—new views of Liebig as to its influence on the growth of plants—outline of the arguments on which they are founded—plants contain more carbon than could have been furnished by the most soluble modifications of humus—insufficiency of all the rain-water received by the earth to dissolve the required quantity of humates—equal amounts of carbon produced by equal surfaces, whatever the crop, and whether manured or not—invariable proportion of carbonic acid and oxygen in the atmosphere—maintained by the decomposition of carbonic acid by plants—experimental proof that plants give out oxygen—examination of experiments supposed to refute this—humus furnishes young plants with carbonic acid—the process of assimilation traced through all stages of growth—excrements of plants return to the soil more humus than they received from it.

All fertile soils contain a substance derived from the decay of vegetable matter, called *humus* or mould. That it exerts in some way or other a beneficial influence on vegetation there can be no doubt, but it is a question what office it performs in promoting the growth of plants; an inquiry which is of the utmost

importance in all investigations which have for their object to discover by what means their fullest developement may be promoted, or, in the language of the farmer, large crops of them may be obtained. Vegetable physiologists have hitherto assumed that the humus of the soil is extracted from it by the roots of plants, and is the principal source from which they derive their nutriment. Dr Liebig, in the work before mentioned, combats this assumption, and contends that vegetables derive their carbon from the atmosphere; and that the only mode in which the humus of a soil acts is, by furnishing them in the early stages of their growth with an atmosphere of carbonic acid, which is taken up by the tender roots before the leaves are sufficiently developed to assimilate carbon from the air.

An announcement so novel, which strikes so directly at opinions long prevalent both among the scientific and the ignorant, and at the same time of so much importance in our endeavours to found a perfect and rational system of agriculture on the basis of chemistry, ought not to be received merely on the authority of a name however illustrious. I shall therefore give an outline of the principal facts and arguments on which this conclusion is founded.

"Since the time of the immortal author of Agricultural Chemistry," says Dr Liebig, in his preface, "no chemist has occupied himself in studying the application of chemical principles to the growth of vegetables and to organic processes. I have endeavoured to follow the path marked out by Sir H. Davy, who based his conclusions only on what was capable of inquiry and proof." Conducting his inquiries on these principles, this great organic chemist maintains the above-

mentioned views as to the mode in which humus acts, on the following grounds:

1. Its insolubility as it exists in the soil, and its consequent incapability of being absorbed by the roots, and the non-existence in the soil of those artificial modifications of humus which are soluble, though but sparingly so.

2. The great excess of carbon (the only element which plants could derive from humus) produced on a given area above what they could receive from the soil, even if humus existed there in its most soluble state.

3. The insufficiency of all the rain-water which falls upon a given surface to dissolve even the most soluble modifications of humus, in sufficient quantities to furnish the carbon contained in the crops produced in that surface.

4. The uniform amount of carbon on the same space, in crops of the most opposite kinds, on unmanured as well as manured land, and its increase in the soil of woods and meadows, though a certain amount is annually abstracted in the shape of wood and hay.

5. The invariable quantities of oxygen and carbon existing in the atmosphere; the necessity of some process in nature for restoring the oxygen abstracted by the processes of respiration and combustion.

6. The fact that such a process exists, established by repeated experiments, which prove that the leaves and green parts of plants decompose carbonic acid, retaining its carbon, and returning its oxygen to the atmosphere.

Insolubility of humus.—Humus as it exists in the soil is soluble in alkalies—sparingly soluble in water; for if good mould be treated with cold water the fluid

remains colourless, and is found to have dissolved less than $\frac{1}{100,000}$ of its weight of organic matter, and to contain merely the salts which are present in rain-water. The decayed wood of oak, beech, and fir, likewise yields only slight traces of soluble materials.

There are modifications of humus obtained by treating peat, woody fibre, soot, or brown coal, with alkalies—by decomposing sugar, starch, and sugar of milk, by means of acids, and by exposing alkaline solutions of the tannic and gallic acids to the air.

Modifications of humus soluble in alkalies are called *humic acid;* those which are insoluble are called *humin* and coal of humus. Humic acid thus prepared varies in the amount of carbon contained in it from 57 to 72 per cent., according to the nature of the process and the materials employed. When first precipitated it is a flocculent substance, soluble in 2,500 times its weight of water; and it combines with alkalies, forming compounds soluble in no greater degree. There is not the shadow of a reason for supposing that humic acid, or any of the artificial modifications of humus, exist in the soil under the form, and endued with the properties of the vegetable constituents of mould, although vegetable physiologists have confounded the two together—an error which has retarded our knowledge of the true nutritive process in vegetables, and deprived us of our best guide to a rational practice of agriculture.

Aware of the insolubility of humus as it exists in the soil, and agreeing as to the impossibility of the roots taking up any matter in a solid state, they have endeavoured to explain the influence which they assume it to possess in the nutrition of plants, by imputing to it the properties of humic acid as pre-

pared artificially; but even this is very sparingly soluble in water, and when dried or exposed to a freezing temperature it becomes insoluble. If therefore the humic acid of chemists existed in the soil, or if the constituents of mould possessed the properties of humic acid, the heat of summer and the frost of winter would destroy its solubility.

Vegetables contain more carbon than could have been taken up by them in the form of the most soluble compounds of humus.

To obviate the above-mentioned difficulty it has again been assumed, that the lime and alkalies which are found in the ashes of all plants had combined with humic acid, forming soluble salts capable of being taken up by the roots, and converted into carbon by the other organs of plants. This assumption Liebig disproves by shewing from the known quantities of the alkaline bases and earths contained in plants, that the quantity of carbon which could possibly be absorbed by them from the soil in this form is much less than that actually contained in them. In this calculation he proceeds on the assumption most favourable to the hypothesis which he opposes, namely, that the humic acid is taken up by the roots in the forms of humate of lime, and that soda, potash, and manganese, have the same capacity as lime for humic acid.

Berthier found that 1,000 lbs. of dry fir-wood yielded 4 lbs. of ashes; and that in every 100 lbs. of these ashes, after the chloride of potassium and sulphate of potassa were extracted (the bases of which could not have acted as bases to humic acid), there were 53 lbs.

of metallic oxides, potassa, soda, lime, magnesia, iron, and manganese.

Now a Hessian acre of land, equal to 26,910 square feet English measure, produces annually on an average 2,920lbs. of dry fir-wood, containing 6.17lbs. of metallic oxides; and as one pound of lime combines with 12lbs. of humic acid, the above 6.17lbs. of metallic oxides would introduce into the trees 67lbs. of humic acid, which admitting it to contain 58 per cent. of carbon, would be equal to only 100lbs. of dry fir-wood, whereas the quantity actually produced is 2,920lbs.

The same calculation is then applied to wheat, and it is shewn, that in this way the wheat grown on one Hessian acre could not receive more than 63lbs. of humic acid, corresponding to 93.61bs. of woody fibre, but, exclusive of roots and grain, the straw produced, which is identical in composition with woody fibre, amounts to 1,961lbs.

Insufficiency of the rain water which falls on a given area to dissolve the required quantity of humates.

The quantity of rain which falls at Erfurt, one of the most fertile districts of Germany, during the four months from April to July inclusive, is 19.3lbs. over every square foot, equivalent to 771,000lbs. on the Hessian acre, containing 26,910 square feet English measure. Assuming all this water to be absorbed by a plant which comes to maturity during that period, so that none is lost by evaporation, that all this water is saturated with humate of lime, the most soluble salt of humic acid, and that which contains the largest portion of it, the crop could not receive

more than 330 lbs. of humic acid, corresponding to 191 lbs. of carbon; but this extent of land produces in grain and straw (exclusive of roots) 2,843 lbs. equivalent to 1,124 lbs. of carbon, and in beet-root (exclusive of leaves and small fibres) 22,000 lbs. corresponding to 1,032 lbs. of carbon. It is evident, therefore, that these crops derived from some other source much more carbon than they could possibly have absorbed in the form of humates soluble in water.

Equal surfaces of land yield equal quantities of carbon, whatever the crop, and whether manured or not.

The produce of an acre Hessian measure is, in

	lbs.		lbs.	containing per cent.		lbs. of carbon.
Wood	2,920			38	or	1,109
Hay	2,755			44.31		1,111
Corn	2,842	Rye	881	43	379	1,124
		Straw	1961	38	745	
Beet-root	22,000					1,032

There is, therefore, a scarcely appreciable difference in the quantity of carbon produced by land of average fertility, under very different conditions, and yielding crops of very different kinds. The unmanured wood and meadow produces very nearly as much as the manured arable land. Carbon, again, is extracted from the soil every year in the form of wood and hay, and yet from the decay of leaves and branches, and from other matters returned to it by the plants, it becomes richer instead of poorer in carbon. That element must, therefore, have been derived from some other source than the humus of the soil; and as the soil does not yield it, that source must be the atmosphere.

The quantity of oxygen and carbonic acid in the atmosphere being invariable, there must be some natural process to compensate for the abstraction of oxygen by combustion and respiration.

The quantity of oxygen contained in the atmosphere, however great, is not inexhaustible. One man consumes by respiration twenty-five cubic feet in twenty-four hours, and the annual abstraction of oxygen by the combustion of fuel in a town of seven thousand inhabitants is not less than five hundred and fifty-one millions of cubic feet; and yet the condition of the atmosphere with respect to oxygen remains invariable; the air found in jars buried in Pompeii eighteen hundred years ago, contains as much oxygen as that which constitutes our present atmosphere. From what source is the supply derived, and what becomes of the carbonic acid generated during the process of respiration and combustion, for the billions of cubic feet of oxygen abstracted are converted into an equal bulk of carbonic acid, since oxygen does not change its volume by uniting with carbon? From the results of a number of careful experiments, made during several years, it appears, that though the quantity of carbonic acid contained in the atmosphere fluctuates with the seasons, the annual average is constant, and is nearly equal to one thousandth of its weight. Nor is there any reason to believe that the quantity has augmented, although the immense volume generated by animal respiration and combustion ought to produce a perceptible increase. There must, therefore, be some process in nature by which the equilibrium is maintained, by the withdrawal of carbonic acid and resto-

ration of oxygen. This compensating process exists in the vital economy of plants. It has already been shewn that they contain more carbon than they could have obtained from the soil, even supposing humus soluble in water, which it is not, and that they therefore must derive it from the atmosphere in which carbon exists only in the form of carbonic acid. Carbon and the elements of water are the chief constituents of plants; but the relative quantity of oxygen in the whole vegetable mass is much less than in carbonic acid; for that contains two equivalents of oxygen, while water contains only one: and the water decomposed by plants in assimilating hydrogen is amply sufficient to furnish all the oxygen which enters into the composition of vegetable products; for the number of those, such as the vegetable acids, which contain oxygen in larger proportion than that in which it combines with hydrogen to form water, are comparatively few, while many, such as wax, oils, resin, &c., contain hydrogen in great excess. All the oxygen, therefore, which is liberated by the fixation in a plant of the carbon of carbonic acid, must be returned to the atmosphere, and every volume of carbonic acid consumed will furnish an equal volume of oxygen.

Experimental proof of the absorption of carbonic acid by plants.

That plants possess this power of decomposing carbonic acid has been ascertained by experiment; for if the leaves and other green parts be placed in water, and exposed to the light of the sun, the presence of which is indispensable to the process, the

carbonic acid disappears from the water and oxygen is evolved, which, if the experiment be conducted under a glass receiver filled with water, may be collected and examined. The emission of oxygen ceases when all the carbonic acid contained in the water is decomposed, but recommences on the addition of a fresh supply. Oxygen is not emitted by plants when placed in water destitute of carbonic acid, or which contains alkali. Plants increase in weight during this decomposition of carbonic acid; and the increase of weight is greater than the quantity of carbon assimilated; the elements of water must therefore be assimilated at the same time.

To the decomposition of carbonic acid by the leaves of plants, the presence of the solar light is essential, but the absorption of water and carbonic acid by means of the roots is a process in constant action independent of the presence of light. When plants are in the shade during the day, and also during the night, carbonic acid accumulates in all their parts; and the assimilation of carbon and emission of oxygen commence the moment they receive the first rays of the sun.

The atmosphere was found by Saussure to contain more carbonic acid during the night than the day; and it was also ascertained by him, that the upper strata of air contained a larger portion than the lower, which are in contact with plants. Tropical regions, where the sun shines with great power on a luxuriant vegetation, are the great source of oxygen; cold climates, where the artificial warmth of combustion is called in aid of the deficient heat of the sun, furnish the chief supply of carbonic acid. They are blended by means of those currents and counter-currents, from

the equator to the poles, and from the poles to the equator, which are caused by the revolution of the earth on its axis.

Thus not only do plants supply nutriment to animals, but in their living state they furnish to the medium in which both exist that which is essential, and deprive it of that which is noxious to animal respiration. Plants and animals contribute to the well-being of each other by mutually inspiring that which the other exhales. By such simple, beautiful, and harmonious laws is the mechanism of the universe governed!

Refutation of inferences drawn from experiments supposed to favour a contrary conclusion.

The decomposition of carbonic acid by plants is supposed to be disproved by some experiments made by Ingenhouss, from which it appeared, *that in the dark* carbonic acid is exhaled by plants, and oxygen absorbed. The nature of the process is, however, indicated by the fact that the whole volume of the air is at the same time diminished; consequently the quantity of oxygen absorbed must exceed that of the carbonic acid evolved. This, therefore, is not a vital function, like that by means of which plants assimilate carbon during the day, but is a true chemical process, which takes place in dead as well as in living plants, and during which the oxygen of the air acts upon the substances which compose the leaves, blossoms, and fruit, converting volatile oils into resins, and effecting the formation of acids.

The substances of which different kinds of leaves are composed being known, the amount of oxygen

which they will absorb during the absence of light may be calculated with ease and certainty. Thus the leaves which contain volatile oils, or the constituents of gall-nuts, or compounds containing nitrogen, ought to absorb more oxygen than those which contain no such matters, and this theoretical conclusion is verified by experiment; for the leaves of *pinus abies* containing volatile and resinous oils absorb 10 times, those of *quercus robur* containing tannic acid 14 times, and the balmy leaves of *populus alba* 21 times, the quantity absorbed by the tasteless leaves of *agave Americana*. That the formation of acids takes place during the night, is proved by the fact, that the leaves of certain plants (*cotyledon calycinum* and *cacalia ficoides*) are sour in the morning, tasteless at noon, and bitter in the evening. They loose their acid properties during the day, by parting with some of their oxygen, and acquire those tasteless and bitter properties which distinguish compounds containing oxygen and hydrogen, either in the proportion in which they form water, or with an excess of hydrogen. Dead leaves likewise are found by experiment to absorb oxygen in proportion to the facility with which they change colour; those of the holly absorb only 0.86 of their volume of oxygen, while those of the poplar absorb 8 times, and those of the beach 9½ times their volume.

The carbonic acid given out by plants in the night is that which was absorbed, dissolved in water, by means of the roots; it ceases to be decomposed with the departure of daylight, and pervading all the juices of the plant, escapes in quantities proportioned to the water evaporated.

The opinion that carbonic acid constitutes the

food of plants, is supposed by some to be refuted by the results of some experiments on the seeds of balsamines, cresses, and gourds, which were sown in powdered Carrara marble, and supplied with water containing carbonic acid. Though the seeds germinated under such circumstances, the plants died before they reached the third leaf. These experiments, however, must be regarded as utterly worthless for the decision of the question. Many conditions are essential to the well-being of plants, and some genera require peculiar conditions. The food which can serve for the nourishment of a plant must contain all its elements. These may be united in one substance, or may exist separately in several. Milk is the only food which is capable singly of supporting the life of animals. We know of no such single nutriment prepared by nature for the sustenance of plants. They derive their nutriment from a variety of substances containing the elements which enter into the composition of their several organs, and no one of these is sufficient without the others. Dogs cannot live if fed exclusively on gelatine, or on white bread, or on starch, all nutritious substances, neither can a plant reach maturity if fed only with carbonic acid. Besides those matters which form the principal constituents of plants and animals, they require other inorganic substances, although we are ignorant of the peculiar functions performed by those substances: animals cannot live if totally deprived of common salt, neither can plants live unless supplied with certain metallic oxides. A plant of the family of *gramineæ* (corn and grasses), or of the *equisetaceæ* (or horsetails), the solid framework of which consists of silicate of potassa, cannot be brought to maturity without silicic acid

and potassa, nor a plant of the genus oxalis without potassa, nor saltworts (*salsosa* and *salicornia*) without chloride of sodium, or some salt of similar properties. Experiments conducted under a glass globe, from which all the elements entering into the composition of plants are, with one exception, systematically excluded, are far less calculated to advance our knowledge of the sources from which plants obtain their food, than the study of a forest or a meadow where they grow in a state of nature. When we know the constituents of the soil, and are acquainted with the composition of the atmosphere, and of rain-water, we are in possession of all the conditions necessary to the life of the plants which it supports.

Humus supplies the young plants with Carbonic Acid.

Having by facts and arguments like these established the conclusion, that plants, instead of drawing their nutriment from the humus of the soil, absorb by means of their leaves their carbon from the atmosphere, Dr Liebig proceeds to shew that the only function of this humus is to supply plants in the early stages of their growth with an atmosphere of carbonic acid, which is absorbed by the roots before the leaves are sufficiently developed to decompose that which exists in the air.

Humus is the result of the decay of vegetable fibre. Decay is a slow process of combustion, by which woody fibre converts the oxygen of the air in contact with it into an equal volume of carbonic acid. The presence of water is necessary to this process,

which is extremely gradual; alkalies promote, acids retard it. The conversion by woody fibre of the surrounding oxygen into carbonic acid, diminishes as decay advances, till a brown, coally looking substance remains, which no longer possesses the property; it constitutes the principal part of all strata of brown coal and peat.

The process of decay by which oxygen is converted by humus into carbonic acid, goes on, in a soil permeable to air and moisture, in the same manner as in the air itself. The cultivation of the land by stirring and loosening the soil, promotes decomposition by removing the carbonic acid surrounding the particles of humus, and bringing them in contact with fresh supplies of oxygen. The loosening of the soil round young plants favours their growth by increasing the supply of carbonic acid, whilst every thing which tends to *bind* the soil and prevent access of air diminishes the supply of food. As the roots increase, they remove the carbonic acid which protects the humus from further decay; it is replaced by atmospheric air, and fresh carbonic acid formed.

When the organs by which a plant obtains carbonic acid from the atmosphere are sufficiently developed, it no longer requires that contained in the soil, and during the heat of summer it derives its carbon entirely from the atmosphere. When the nutriment which a plant receives is greater than its existing organs require, the excess is not returned to the soil, but gives rise to new organs—new cells, twigs, and leaves; and as the power of absorbing nutriment is proportionate to the surface of the leaves, every increase of these organs produces an increased power of obtaining nutriment. When the leaves and other green parts are fully matured, the new products

arising from this continued assimilation are no longer employed in the formation of fresh leaves and branches; they produce woody fibre, starch, sugar and acids, which were previously formed by the roots when required for the developement of the stem, leaves, and branches. When the formation of woody fibre has reached a certain stage, the supply of nutriment which still continues is appropriated to the formation of blossoms and fruit. On the ripening of the fruit the functions of the leaves cease, because the plant has now reached its fullest developement, the chemical action of oxygen on them commences, they change colour and fall off. Between the blossoming and ripening of the fruit new compounds are formed by means of organic chemical "transformations." These transformations are not due to the power of the "vital principle" of physiologists, but are a true chemical process arising from disturbance in the attraction of the elements of a compound, although they take place in another form from the ordinary decomposition of salts, oxides, and sulphurets. The formation of sugar during the germination of seed, and the solution of muscular fibre, have both been ascribed to the vital principle; but the vital principle cannot exist in a decoction of malt in the stomach of a dead calf, and yet when starch is introduced into the former, it converts it first into gum, and afterwards into sugar; and hard boiled albumen and muscular fibre have been dissolved in a decoction of a calf's stomach to which a few drops of hydrochloric acid were added.

Of the new compounds formed by these chemical transformations, some remain as component parts of the blossoms and fruit, some pass off in the form of excrements. From the food which it receives, each organ takes that which it requires for its own suste-

nance; and the superfluous elements combining together are thrown off as excrementitious matter. Matters rejected by one organ contain the elements which enter into the composition of others, till, being incapable of further transformations, they are thrown off from the system—gaseous matters by the leaves and blossom, solid excrements are deposited in the bark, soluble substances are passed off by the roots. These secretions are most abundant just before the formation and during the continuance of the blossom, and diminish after the developement of the fruit. The excrementitious matter which the soil absorbs from the roots is still capable of decay, and of being converted into carbonic acid. It becomes in fact humus. By means of these excrements—of the fallen leaves of trees and of the old roots of grasses—the soil of forests and meadows receives more carbon than its decaying humus had lost in the shape of carbonic acid.

Plants have been brought to maturity on a small scale without the assistance of humus or mould. They have also been found to thrive in powdered charcoal, in which they will blossom and bear fruit if exposed to the influence of rain and the atmosphere. The only substances which the plants can derive from charcoal are a few salts, those of silica of potassa among others, but it possesses the power of condensing gases within its pores, more particularly carbonic acid, and it is thus enabled, like humus, to supply the roots with an atmosphere of carbonic acid. Plants however will not arrive at maturity if watered with pure distilled water, instead of rain or river-water. Rain water, therefore, must contain some substance essential to vegetable life, and that substance will be shewn hereafter to be nitrogen in the form of ammonia.

SECTION II.

SOURCE OF THE HYDROGEN OF PLANTS—OF THEIR NITROGEN—IMPORTANCE OF THEIR INORGANIC CONSTITUENTS.

Plants obtain nitrogen by decomposing water—they obtain their nitrogen from the atmosphere in the form of ammonia—ammonia too much diffused in the air to be detected till concentrated in rain water—discovered by Liebig in rain-water and snow—and in the juices of plants—increase of azotized products by the use of ammoniacal manures—gypsum and burned clay fix the ammonia of the atmosphere in the soil—charcoal absorbs ammonia—the metallic oxides found in the ashes of plants essential to their existence—their constant presence in combination with organic acids—invariable quantity of oxygen present when one base is substituted for another—small quantity of alkalies in plants which flourish on a variety of soils—potash restores the fertility of exhausted land—if these bases were not essential they would not be retained by the plant.

The hydrogen of plants is obtained by the decomposition of water.

Woody fibre consists of carbon united with oxygen and hydrogen in the proportion in which those two elements are combined in water, but ordinary wood contains an excess of hydrogen above that proportion, arising from the presence of the green principle of the leaf, wax, resins, volatile oils, and other compounds abounding in hydrogen. Most plants contain hydrogen in the form of water, which

may be separated as such; but the hydrogen, which is essential to their constitution, cannot possibly exist in the state of water. To furnish the hydrogen, therefore, of woody fibre, of wax, resins, and other compounds of that nature, plants must possess the faculty of decomposing water, for from no other body could they obtain hydrogen; and the elements of water have such a powerful and extensive range of affinity, that no compound is more easily decomposed, or performs more important offices in the phenomena of combination.

Plants, therefore, derive their carbon from the decomposition of carbonic acid, and their hydrogen from the decomposition of water; and in the formation of woody fibre, which consists of carbon united with the elements of water, in the same proportion in which those elements are combined in that fluid, an equal amount of oxygen will be set free, whether we suppose that carbon combines directly with water, or, which is more probable, that during the decomposition of carbonic acid and water, part of the oxygen of the former combines with the hydrogen of the latter. In either case, two equivalents of oxygen will be liberated in the form of gas; for water and carbonic acid contain between them three equivalents of oxygen, namely, two in carbonic acid, and one in water, which, in the latter, is united with one equivalent of hydrogen; and woody fibre contains, besides its carbon, one equivalent of hydrogen, and only one equivalent of oxygen.

Plants derive Nitrogen from the Atmosphere in the form of Ammonia.

Nitrogen exists in small quantities in every part of vegetable structure; it is most abundant in the seeds.

Plants may be brought to maturity in charcoal, provided they are supplied with rain-water. Rain-water can only contain nitrogen dissolved in atmospheric air, or in the form of ammonia, that is, in combination with hydrogen. The nitrogen of the air cannot be made to enter into combination with any element except oxygen, by the most powerful means; neither do nitrogen and hydrogen unite, except in their nascent state, that is, when in the act of liberation from other bodies; and so far from there being any reason to suppose that nitrogen, as it exists in the atmosphere, enters into the composition of plants, we know that many species emit the nitrogen absorbed by their roots either in the gaseous state, or dissolved in water; and, on the other hand, it is equally well known that the formation by plants of substances containing nitrogen, such as gluten, is proportioned to the quantity of nitrogen conveyed to their roots in the form of ammonia. Ammonia, moreover, possesses the same aptitude for decomposition and transformation as water, together with properties which belong to no other compound of nitrogen, being extremely soluble in water, forming soluble compounds with all acids; and when in contact with other bodies, completely resigning its properties as an alkali, and becoming capable of assuming the most various and opposite forms.

The increase of nitrogen in the soil, notwithstanding the annual abstraction of a considerable quantity in the form of animal and vegetable products, may be regarded as a proof that it is derived from the atmosphere in the form of ammonia. On a well-cultivated farm, large enough to maintain its cultivators without assistance from other quarters, there will be a certain quantity of nitrogen contained in the produce of the land, and in the bodies and excrements of the men and animals which feed upon them. The whole produce will not be consumed on the farm; a certain quantity of corn and cattle will be exported annually; and though no compounds containing nitrogen be brought back in return for the portion thus abstracted, the quantity of nitrogen on the land will be found to have increased after a given number of years. The nitrogen in the excrements cannot reproduce itself, and the soil cannot yield it; it must therefore be derived from the atmosphere.

Source of Ammonia in the Atmosphere.

The last products of the decay of animal bodies are *ammonia* and *nitric acid*, the former in cold and temperate latitudes, the latter in hot regions; and in those cases where nitric acid is the result of animal decomposition, the nitrogen must first have united with hydrogen to form ammonia, and must subsequently have been converted by oxidation into nitric acid; for it is only with the greatest difficulty that nitrogen can be made to unite directly with oxygen; but ammonia cannot be exposed to the action of oxygen without the formation of nitric acid. In all climates, therefore, ammonia must be formed by the

decay and putrefaction of animal bodies, and that in large quantities. The dead bodies of thirty millions of human beings, besides innumerable millions of animals, annually yield their nitrogen to the atmosphere in the form of ammonia, capable of entering into combination with carbonic acid, and forming volatile compounds. In these volatile compounds, and in its gaseous state, it is extremely soluble in water. It will therefore be dissolved in the aqueous vapour with which the air is always charged, and which, when saturated with moisture, it lets fall as rain.

Difficulty of detecting Ammonia by analysis of the Air; its concentration in Rain-water and Snow.

It may be calculated from certain known data, that a pound of rain water is diffused when in the state of vapour through 11,471 cubic feet of air. This is the reason that chemical analyses have failed to detect the presence of ammonia in the atmosphere; for if one grain of ammonia were contained in the aqueous vapour of this 11,471 feet, then the proportion contained in 10 cubic inches, the quantity usually operated upon, must be too small to be appreciable by the most delicate analysis, even were it ten thousand times greater. But when the ammonia diffused through this 11,471 feet is condensed in a pound of rain-water, its detection becomes much easier. If a pound of rain-water contains only $\frac{1}{4}$ of a grain, then an acre English measure will receive annually 133 lbs. of ammonia, corresponding to 109 lbs. of nitrogen, which is more than is contained in the form of vegetable gluten and albumen in the wood, hay, or beet-root, which grows on that surface, but less than that con-

tained in the straw, roots and grain of the corn-crop which would be produced on the same area*.

Ammonia exists in Rain-water and Snow.

The existence of ammonia in rain-water and also in snow has been demonstrated by experiments made in the laboratory at Geissen. Since this fact was first announced by Dr Liebig, the experiments have been repeated by many in France, Germany, England, and America; and they may easily be repeated by any one who wishes to satisfy himself on the subject, by evaporating a few pounds of rain-water or snow in a clean porcelain basin or soup-plate, with the addition of a few drops of hydrochloric acid. When the liquid is evaporated nearly to dryness, crystals of sal ammoniac will form, which on being treated with slaked lime in powder will give out the well-known pungent fumes of ammonia.

The quantity of ammonia present in rain-water varies with the season. It is less in the winter than in the summer, greater during the first than during the last of several wet days, and most abundant of all in the rain of a thunder storm after a long continued drought. It was found also in the experiments at Geissen, that the lower layers of a fall of snow ten inches deep contained more ammonia than the upper layers, which of course fell the last.

* It has already been stated that 26,910 square feet English measure, receive 770,000 lbs. of rain in four months, or 2,310,000 lbs. annually. An English acre, or 43,560 square feet, must therefore receive 3,739,264 lbs.

Presence of Ammonia in the juices of Plants.

Not only has Dr Liebig demonstrated the presence of ammonia in rain-water, but he has ascertained that it exists in the juices of plants, from which we may conclude that it is taken up with rain-water by means of the roots. The discovery was unexpectedly made by him while engaged in investigating the quantity of sugar contained in the juices of several varieties of maple growing upon soils that were not manured; when he found that a great quantity of ammonia was emitted by the juice on being mixed with lime in the process of crystallizing and refining the sugar. He afterwards extended these observations with the same results to the juice of birch-trees grown in a wood several miles from any habitation. Ammonia was detected by the same means in the water that exudes from vines that *bleed*, as it is called, when newly cut. In these cases the ammonia was contained in the juices of the stem; but it exists in every part of plants—in the roots, as may be known by the smell of ammonia in manufactories of beet-root sugar, where large quantities of the juice are purified with lime to free it from vegetable albumen and gluten, before evaporating it for crystallization—in the unripe gelatinous pulp of the almond and peach when treated with an alkali—in all blossoms and unripe fruit, and in the leaves of tobacco.

The use of Ammoniacal Manures proves that Plants received their Nitrogen in the form of Ammonia.

Another proof that the nitrogen of vegetables is derived from ammonia, is found in the fact, that the

use of animal manure, by increasing the quantity of ammonia supplied to the roots of a plant, increases not only the number of seeds produced by the different kinds of corn, but also the proportion of gluten contained in the seed. Wheat, rye, and barley, contain different quantities of gluten; and the proportion varies even in the same kind of grain, as will appear by the comparison of the analyses of them by several eminent chemists.

The following are the quantities of gluten contained in the wheat of different countries:

French	12.5	per cent.
Alsace	17.3	.....
Barbary	19	.....
Sicilian	21	.....
English	24	.....
Wheat grown in the Jardin des Plants	26.7	.....

That these various proportions are to be ascribed to a difference in the quantity of ammonia supplied to the plants under different modes of culture, may be concluded from the fact, that wheat grown on land manured with cow-dung, which contains the smallest quantity of nitrogen, yielded only 11.95 per cent. of gluten, while 35.1 per cent. was obtained from wheat manured with human urine, which abounds, when in a putrid state, in the carbonate, phosphate, and lactate of ammonia, and contains nitrogen in no other form than that of ammoniacal salts. In the solid excrements of animals there is less nitrogen than in their urine; there is less also in that of horses and horned cattle than in that of carnivorous animals, and of the

human species, which is therefore the most powerful manure for vegetation, requiring much nitrogen. Human urine contains nitrogen in the form of ammonia, and urea, which latter is converted during putrefaction into carbonate of ammonia. These facts place in a strong light the importance of liquid manures in general, and of human urine in particular, which, though they have been long used and highly prized in Flanders, Germany and China, are in this country most unaccountably neglected. But as this subject will come more properly under consideration, when treating of manures, it will be reserved for future discussion.

Gypsum fixes the Ammonia of the Atmosphere.

The benefits derived from the use of gypsum and burnt clay as manures depend on properties which they possess, and which will be more fully explained hereafter, of fixing in the soil the ammonia which exists in rain-water as the carbonate, one of its most volatile forms, and which is therefore extremely liable to be dissipated by evaporation. Gypsum decomposes this carbonate, and converts it into sulphate of ammonia, a soluble but not volatile salt. Burnt clay performs a similar office towards the ammonia conveyed to the soil with the rain, owing to properties which the oxides of iron and alumina contained in it possess of attracting ammonia from the atmosphere and retaining it.

Powdered charcoal surpasses all other substances in the power which it possesses of absorbing gases in its pores. Decayed oak-wood approaches very near to charcoal in this respect; and as humus is, as was

before shewn, nothing but woody fibre in a decaying state, we may see in this fact another cause of the beneficial action of the humus of the soil on plants: it not only supplies them with an atmosphere of carbonic acid, but is one of the means of procuring for them the nitrogen necessary for their perfect developement.

The Alkalies and Alkaline Earths found in Plants essential to their existence.

Having shewn from what sources and by what means plants obtain the four elementary substances which constitute the principal part of all vegetable structure, namely, their carbon, oxygen, and hydrogen, from the decomposition of water and the carbonic acid of the atmosphere, and their nitrogen from ammonia, which is the product of the decomposition of animal substances, and is conveyed to them dissolved in rain-water, Dr Liebig proceeds to investigate the functions in the vegetable economy performed by those inorganic bases, potassa, soda, lime, and magnesia, which are found in the ashes of all plants, and which some have supposed to be generated by them, while others regard them as mere accidents derived from the soil. The views which he entertains respecting these inorganic bases are as novel and important as those which he has promulgated respecting the functions of humus. He contends that they are essential to the growth of plants, and that different families of them require some one base, some another.

The following are the reasons from which he concludes that they are essential to the perfect developement of the vegetable structure.

1. Certain organic acids are peculiar to certain families of plants, and are constantly present in them; they must therefore be considered essential to their existence; and as they are always combined with inorganic bases, those bases must likewise be essential.

2. Some of the alkalies and alkaline earths appear more appropriate than others to certain tribes of plants; and though these vary to a certain extent with the nature of the soil, and though one base may be substituted for another, the amount of oxygen contained in all the bases is the same as it would have been had no such substitution taken place, and depends upon the capacity for saturation of the organic acids contained in the plant.

3. When the alkalies in a soil have been exhausted its fertility diminishes until the alkalies are restored.

4. If these bases were not necessary to the growth of plants, they would be separated as excrement, and returned to the soil when accidentally taken up by the roots.

I. *Constant presence of organic Acids in combination with inorganic bases.*

Most plants, if not all, contain organic acids combined with potassa, soda, magnesia, or lime; for organic salts always yield carbonates by incineration, and the ashes of all plants contain carbonates of those alkalies and earths. These bases regulate the formation of the acids; for the diminution of the one is always accompanied by the diminution of the other: for instance, the quantity of potassa as well as the

quantity of tartaric acid is greater in the unripe than in the ripe state of the grape.

The acids are always present; they are more abundant in those organs which produce substances conveyed to them for assimilation, than in those in which the process of assimilation is more active; (in the leaves, for example, than in the branches, and in the branches than the stem)—they are always in the form of salts of inorganic bases; and as some of them are peculiar to certain families, the tartaric acid, for instance, to the vine, the oxalic acid to wood-sorrel, we must regard them as exercising an important influence in the developement of the fruit and seeds, and as performing other functions with the nature of which we are unacquainted. But if the acids are of this importance, of the same importance to the vegetable economy must the bases be, for the two are invariably combined.

II. *Invariability of the quantity of Oxygen contained in the alkaline bases.*

The alkaline bases occur in plants in the form of acid, not neutral salts; and on this circumstance depends the quantity of alkaline bases, because as the capacity of acids for saturation is invariable, and as there is no reason to suppose that a plant in a state of nature produces more acid than is necessary, it must contain an invariable quantity of alkaline base. But the capacity of an acid for saturation, or the power of a base to neutralize an acid, depends upon the quantities of oxygen contained in them, which, by the law of definite proportions, must either be equal or multiples of one another. One equivalent of pro-

toxide of iron, for instance, combines with one equivalent of sulphuric acid. The first contains one, the other three equivalents of oxygen. The quantity of oxygen in the one is therefore a multiple of the quantity contained in the other. Again, one equivalent of sulphuric acid combines with three equivalents of peroxide of iron containing three equivalents of oxygen. The oxygen of the base and acid are in this case equal.

When also an acid combines with a number of different bases, as potassa, soda, lime, &c., however the quantity of a base may vary the *quantity of oxygen contained* in them collectively is the same. We might expect, therefore, laws of combination in definite proportions to govern the inorganic matter which enters into the organs of plants, and to produce the same results; for the vital principle does not alter the laws under which chemical forces act, it only directs their action in subordination to those laws; and accordingly we find, that though of two plants of the same kind growing on different soils the ashes of one may contain a base which is not present in those of the other, and though the proportions of those bases which are common to both may widely differ in the two cases, yet the amount of oxygen contained in the alkaline bases of each will be the same.

The ashes of a pine-tree from Mount Breven contained in 100 parts,

Carbonate of potassa	3.60	containing of oxygen	0.41
..... lime	46.34	.....	7.33
..... magnesia	6.77	.....	1.27
	56.71		9.01

On the other hand, the ashes of a pine from Mount La Salle yielded

Carbonate of potassa	7.36	containing of oxygen	0.85
..... lime	51.19	.....	8.10
..... magnesia	00.00	.....	0.00
	58.55		8.95

These two numbers, 9.01 and 8.95, are so close an approximation to one another, that they may be regarded as identical.

The ashes of two fir-trees grown, the one in Allevard (department of the Isere), the other in Norway, exhibited considerable difference in the quantity of soluble ashes which they yielded, the one containing 50 per cent., the other only 25 per cent.

The ashes of that from Allevard consisted of

Potash and soda	16.8	containing of oxygen	3.42
Lime	29.5	.....	8.20
Magnesia	3.2	.....	1.20
	49.5		12.82

Deduct the oxygen contained in the bases of the hydrochlorates, phosphates, and sulphates, of which the above partly consisted	1.20
Oxygen of carbonates	11.62

The ashes of the fir from Norway contained in 100 parts,

Potash	14.1	containing of oxygen	2.4
Soda	20.7	.....	5.3
Lime	12.3	.....	3.45
Magnesia	4.35	.....	1.69
	51.45		12.84

Deduct the oxygen contained in the bases of the sulphates and phosphates as before	1.37
Oxygen of carbonates	11.47

The quantity of oxygen contained in the carbonates, the bases of which had been united with organic acids, were again in this case such closely approximating numbers as 11.62, and 11.47.

The form in which silica, manganese, and iron, enter into the composition of plants, and what functions the two latter perform in the vegetable economy, is not known. Dr Sprengel, a chemist, who has been long employed in endeavouring to point out the importance of the inorganic ingredients of a soil to the developement of the plants cultivated upon it, considers manganese and iron to be as essential to vegetable life as the alkalies; an opinion in which Dr Liebig does not concur, because they are found only in the form of excrementitious matter in the bark, and never enter into the composition of any organ. But potassa, soda, magnesia, and lime (when the last is not present as an insoluble oxalate), exist in all plants as soluble salts of organic acids. Oxalate of lime, which is found

in lichens, is in them a substitute for woody fibre, and must therefore be regarded as essential to their existence; and this is an additional argument in favour of the soluble organic salts performing offices of equal importance to those plants in which they occur.

III. *Plants containing the smallest quantity of alkaline bases flourish in the greatest variety of soils; and the fertility of exhausted soils may be restored by a fresh supply of Alkalies.*

We have seen in the examples above given, that one alkaline base may be substituted for another, and that when a plant does not find in the soil its appropriate alkali, its place may be supplied by others possessing similar properties. The substitution of one alkali for another can only take place to a certain extent. Corn and vines require a soil containing potassa. Saline plants only flourish where they can obtain soda. No corn-bearing plant can produce seeds yielding flour without a large supply of phosphate of magnesia; the roots of potatoes contain much phosphate of magnesia and ammonia, and a little potassa. In some plants, but we know not in how many, soda and potassa may be replaced by lime and magnesia. With an abundance of lime in the ashes the magnesia decreases; and as the magnesia increases the lime or potassa diminishes. In some plants not a trace of magnesia is to be found.

Plants which contain but a small quantity of alkalies will grow upon a greater variety of soils than those which contain abundance of them.

10,000 parts of oak-wood yield 250 parts of ashes
. . . . . fir-wood . . . 83 . . . . . .

and we find that firs will flourish on barren sandy soils where oaks, which require so much more alkali, will not grow.

All the grass tribe (including the *cerealia*, or corn-bearing plants) which contain much silicate of potassa in their leaves and stalks, abstract a considerable quantity of it from the soil; this is returned with the straw of farm-yard manure to arable land, but not to unmanured meadows, and therefore sandy soils which contain little potash seldom produce a strong crop of grass.

Irrigation supplies the grass of meadows with potassa dissolved in water.

Gypsum produces large crops of hay, and thus causes it to abstract potassa from the soil faster than it can be supplied by the decomposition of the minerals of which it is composed. The consequence is, that after the lapse of a few years the hay crops diminish: but the application of wood-ashes, which abound in potash causes the grass to grow as before. On barren sandy land heath and fir-trees find sufficient potash for their own wants, though the soil does not contain enough to produce a crop of grain. On a heath of this description near Lunenberg a corn-crop is obtained once in thirty years by means of the ashes of the heath-plants, which during that period have accumulated potassa. Similar results are produced on forest-land near Heidelberg, by means of the ashes of the branches, roots, and leaves, which are burned after felling the trees; and without this manure no corn-crop can be raised. In a vineyard near Bingen on the Rhine the vines having been forced for several years by powerful nitrogenous manures destitute of potassa, their produce was found after a time to

diminish; and, on the other hand, vineyards which have been dressed with cow-dung, a manure which contains much potassa, though little nitrogen, have maintained their productiveness for more than a century.

Wormwood, which contains much potassa, having been grown for the purpose of manufacturing the carbonate of that alkali, the consequence was, that the soil thus deprived of it was rendered incapable of producing corn for many years. These facts afford conclusive evidence that the alkalies contained in plants are essential to their growth. It is therefore almost superfluous to adduce the following argument.

IV. *The Alkalies, if not essential, would be separated as excrement.*

The roots of plants imbibe, like a sponge, all substances presented to them in a state of solution. What is suited for assimilation is retained by them, what is superfluous is rejected as excrement. That plants possess the latter power was proved by experiments, in which they were made to vegetate first in a weak solution of acetate of lead, and then in rain-water. The latter was found after a time to have received from them all the acetate of lead which they had previously imbibed. A plant growing in the open air and sprinkled with nitrate of strontian absorbed the salt, but separated it again and deposited it in the soil, and the nitrate being removed further from the roots by every shower, not a trace of it could be found in the plant. The ashes of the fir-tree before mentioned grown in Norway, contained no common salt, though it must have been conveyed by every

shower to the roots and absorbed by them; the only explanation of this fact which can be offered is found in the experiments above mentioned, which prove that plants have the power of excreting substances taken up by the roots which are not necessary to their existence, and therefore that those which they retain are indispensable. These considerations shew the importance of an accurate analysis of the ashes of those species of plants which we cultivate, if we would supply them with the nutriment which they require.

SECTION III.

SOILS—THEIR PERMANENT IMPROVEMENT.

A mixture of the earths essential to fertility—natural processes by which this mixture has been effected—during the formation of rocks—and in the loose covering spread over them—fertility increased by artificial mixtures of the constituents of soils—"claying" in Norfolk—importance of a knowledge of the constituents of soils—tabular view of the analyses of the most fertile soils—of those of medium fertility.

A mixture of the earths essential to the fertility of a soil.

UNDER the guidance of Dr Liebig we have learned that the atmosphere and water furnish our crops with the greater portion of the elements which enter into their composition, and that from the soil they obtain certain inorganic substances, which, though taken up in very small quantities, are essential to their com-

plete developement; and we are now prepared to enter on the consideration of soils and the art of cultivating them. The great object of this art is to promote an extraordinary developement of those parts of plants which are of use to man as food for himself and his dependent animals, or as articles of commerce; and this is done by supplying them with the nutriment necessary for this purpose beyond that quantity which in a state of nature they could obtain from the atmosphere and the soil.

The chief constituents of soils are silica or silicic acid, lime, and alumina. Neither of the two first in their pure state constitute a fertile soil. The sterility of sand is proverbial; extensive tracts of chalk occur in France, which are from their poverty almost uninhabited; and the chalk districts of England support but a scanty population compared with that of other portions of the island which are as exclusively devoted to agriculture. Of calcareous tracts, those limestones afford the most productive soil which contain a portion of alumina.

This mixture effected by nature in the formation of Rocks.

All soils are formed by the disintegration, or crumbling, of rocks; and if they consisted exclusively of the materials of that on which they rest, their barrenness or fruitfulness would be regulated entirely by that of the rock from which they were derived; but a mixture of their constituents has been effected by various natural processes. The rain which falls upon the surface bears with it into the lines of drainage a vast amount of fragmentary matter, which is trans-

ported to different distances proportioned to the magnitude of the fragments and the declivity of the ground, on which depends the velocity of the current: gravel is first deposited; as the transporting power of the stream diminishes, sand is borne further; and a vast amount of matter, so finely divided that it is held in suspension by currents of only moderate velocity, is borne onwards till it reaches the sea. In favourable situations, that is, in the broad parts of rivers, particularly near their mouths, where the velocity is diminished, a considerable portion of this finely-divided matter, collected from various quarters, is deposited on the shores, and forms those rich alluvial tracts, so much coveted by the farmer, which will bear repeated crops without manure. Such soils contain a large portion of fine siliceous sand mixed with alumina and oxide of iron; these form the ingredients which are present in the greatest abundance, but they contain also, though in much smaller quantities, lime, potassa, soda, and magnesia, in the form of carbonates, phosphates, sulphates, and chlorides, together with a little vegetable matter in a state of decay; the action of the last, till the publication of Dr Liebig's work, was not understood, and was supposed to be the sole cause of their fertility. Of the materials borne out to sea, some are carried by currents to more distant shores, where they form similar tracts of alluvial land—some are deposited in the bed of the ocean, where they are forming strata containing the remains of fishes, corals, and shell-fish, like those rocks which form so large a portion of our present continents. There being conclusive evidence that these rocks have been derived from the wearing down of older rocks, and transported by the agency of rivers

into lakes and seas, the beds of which have been converted into dry land by processes of elevation which are now in action, or by others in which forces of greater intensity have been exerted than any which have occurred within the range of human experience, it follows that even in the purest siliceous, calcareous, or aluminous rock, there must be some slight mixture of the different earths. But this mixture has not only been effected by the means we have described, as employed in the formation of the stratified rocks, and of alluvial tracts, on the banks and near the mouths of rivers, which have either been left by the sea or reclaimed by the hand of man; even in more elevated regions, near the source of the drainage waters, an intermixture of the ingredients of two contiguous rocks will take place near their junction in the soil resulting from their decomposition, and will produce in general more fertile land than that composed of the unmixed debris of either.

The fundamental rocks in the vicinity of Hazlemere consist of the Lower Green Sand, which rising from beneath the chalk, constitutes the hills of Blackdown, Hindhead, &c. and the weald clay, a rock still lower in the series, which, emerging from beneath the Green Sand, spreads over that wooded tract known as the Weald of Sussex and Kent. Neither of these constitutes a good soil, but at their junction we generally find a narrow stripe of land of better quality than either, more easily worked than the clay, and which yields better wheat-crops than the sand.

Mixture of earths in the loose covering of the earth.

The mixture of the decomposed materials of which soils are formed has been further effected by another process of nature. It is only in certain situations that

we see the rocks which form the solid framework of the crust of the globe. A loose covering is extensively spread over them, consisting for the most part of the decomposed materials of the rock immediately below, mixed with fragments which have been borne from a distance—sometimes hundreds of miles—by powerful currents of water which have swept over the surface at an epoch, which, though in geological chronology it is comparatively recent, was most probably antecedent to the creation of the human race and of those species of plants and animals amidst which we live.

Thick masses of this loose covering of far-transported fragments, mixed with a much larger proportion of those of the subjacent and adjoining strata, and lodged in situations on the flanks and summits of hills far beyond the influence of the existing lines of drainage, are spread over the slate-rocks of North Wales, and the New Red Sandstone of Cheshire and Shropshire. Large blocks and pebbles, and of course much smaller fragments, are found in it, which can be traced to no nearer source than the granite of Cumberland, or the limestones which occupy the intermediate country. Fragments of a kind of chalk peculiar to the county of Antrim in Ireland, have been found in the south-west extremity of Caernarvonshire. But for this loose covering of far-transported materials, large portions of the districts in question would consist of nothing but a barren surface of hard and naked rocks.

Another example of the beneficial effects of these extraordinary currents by which the dry land appears at that epoch to have been overwhelmed, is furnished by a fertile tract which extends from near Sittingbourne to the foot of Boughton-hill, bounded on the north by the estuary of the Thames, and on the

south by the chalk-hills. The soil is a calcareous loam, formed of the mingled ruins of the chalk, of that stratum of clay called the London clay, and of the sands and gravels which occur towards its lower part. The superior productiveness of this tract of country to the bare sides and summits of the chalk-hills, or to those points where the surface consists of uncovered clay, as between Boughton and Canterbury, or of sand and gravel, as at Bexley Heath, is visible even to the passing traveller.

Fertility increased by artificial mixtures of the earth.

For the improvement of barren soils we have only to copy those natural processes by which an intermixture of the various earths has been effected, and by which the great Author of Nature has provided that many districts should be rendered fertile which would otherwise have been barren, and that the early physical convulsions to which the earth has been subject should prepare it for the abode of the human race.

In a case like that of the Weald clay and the Lower Green Sand, for instance, there can be no doubt that a dressing of the clay would fertilize the sand by communicating to it a portion of that potassa which all aluminous soils contain, and siliceous soils require, and that the sand would be beneficial to the clay by rendering it more mellow, more porous and permeable to air and moisture*. Unburnt chalk would have the same effect, and would also communicate a

* The addition of clay to sandy soils increases the quantity of potash contained in them, and thus produces an improvement in their chemical constitution. The addition of clay to sand

portion of lime to a soil deficient in that earth. Chalk at the rate of from 20 to 40 tons per acre has long been used with great advantage in this form on the London clay of Essex. How far the improvement effected by such mixtures will be commensurate with the expense, must depend upon local circumstances regulating the cost of carriage. In general, the sand on the borders of the weald could be conveyed to the clay at a cheaper rate than the clay can be conveyed to the sand, because from their relative situations the carriage of the sand would be down hill.

It will frequently be found that the subsoil contains at a very slight depth a larger portion of those earths and alkalies which are essential to the growth of plants than are found in the surface soil; and that a mixture of the two will be beneficial.

Claying sands in Norfolk.

Such a mixture has been made with the greatest success in Norfolk. So large a portion of the surface of that county consists of sand, that one of our monarchs is reported to have said of it, that it was only fit to be cut up into roads for the rest of the island. The rock below these sands is in some parts chalk, in others London clay; and between the sand and the rock a mass of drifted materials is interposed. This transported matter consists at some points of gravel, in others of fragmentary chalk mixed with a variable proportion of clay. "Clay" is the local name for this last variety, which is so generally distributed that accumulations of it are to be found

sand merely produces mechanical improvement by increasing the porosity of the soil, unless the sand consists partly of calcareous matter.

at the depth of a few feet below the surface, in almost every field; and by claying the land at the rate of about 150 cubic yards to the acre, large fortunes have been made by men who had leases of considerable tracts of poor land, the value of which was raised by the process from a rent of 3*s*. and 5*s*. the acre, to upwards of 20*s*.

The practice commenced during the latter half of the last century, and is said to have been introduced neither by a practical nor a scientific man, but by one whom his neighbours called in derision the "sky farmer," intimating that he and his farming dropped from the clouds. He was a London shopkeeper, who having purchased or inherited a small property in the county, retired to it and commenced farming with very little knowledge of the business. Farm-yard manure ran short with him, and thinking that one substance carted on the land was as good as another, he finished dressing a field with the clay excavated in digging a pond. The superiority of the crops raised on the land so treated, attracted the attention of his neighbours, and the practice was generally adopted in that and the adjoining counties, wherever a similar subsoil existed, causing land which before produced no other grain than rye or barley, to yield a crop of wheat every fourth year.

Importance of a knowledge of the constituents of soils.

This system originated as we have seen, in a blunder of its inventor, and in his ignorance of the business into which he introduced so vast an improvement. It holds out inducement to experiments on the mixture of different contiguous soils, but it by

no means proves the necessity of such experiments being under the direction of ignorance, or committed to chance. For any thing the "sky farmer" knew to the contrary, he might have been spreading on his land a substance prejudicial to vegetation. Had the clay contained much protosulphate of iron, this would have been the case. If we deviate from established usage, we ought at least to have some good reasons for doing so; and those are only to be found in a knowledge of the substances which plants derive from the soil, and whether those substances are present in the soil or not. There are hundreds of situations where experiments of the same kind would be equally successful; but the only rational mode of conducting them is, to commence by having an analysis of the soil and subsoil made by some experienced chemist, who, in giving the constituents of the surface soil would point out what substances were wanting in it, and whether they were contained in the subsoil. If not present in that, they might be sought, and would in all probability be found as constituents of neighbouring soils and rocks, and then the only question would be, whether the benefit to be derived from them would be commensurate with the expense, or whether they might be supplied at a cheaper rate by other means.

There can be no doubt that the fertility of a soil is much influenced by its physical properties, such as colour, porosity, state of disintegration, and attraction for moisture; but independently of these, it depends on the chemical constituents.

The importance to the perfect developement of plants, of organic acids generated from nutriment derived from inorganic substances, and by consequence

the importance of the alkaline bases with which they are always associated, and without which they cannot be formed, has been shewn in the preceding section. We also find these alkalies associated with certain inorganic acids, such as the sulphuric, silicic, and phosphoric, which they derive from the soil; if therefore the bases necessary for the production of the organic salts, or the acids and bases of the inorganic salts be not present in the soil, constituents indispensable to the formation of the juices, leaves, and fruit of a plant will be wanting, in other words, the plant cannot grow in that soil. The bases necessary for the formation of these salts, are not, however, the same in all plants. Saline plants contain soda only, some soda and potassa, others, as corn, require potassa, lime, and magnesia. It is the same with regard to acids; some plants must have lime and magnesia in the form of phosphates, some must have their alkali combined with silicic acid; while in others it must be in combination with a vegetable acid. Upon these circumstances depends the greater aptitude of a soil for the growth of one plant than another. The application of manure is made with the view of supplying to a soil those elements in which it is naturally deficient, or of restoring to it those of which preceding crops have deprived it. Our attention will be at present confined to the first, by which we seek the permanent improvement of a soil, by the application of clay, marl, lime and other mineral manures. The efficacy of these arises, not only from their supplying what is deficient, but from their bringing into a state of activity substances already existing in the soil, though in an inert state; or from their decomposing some noxious ingredient contained in it.

In our endeavours to improve a barren soil, the most natural, practical, and economical mode of proceeding will be, an examination of its constituents, and a comparison of them with those soils of superior fertility, which will bear repeated crops without manure; and which may be regarded as the standard of the condition to which we would raise other soils, as nearly as circumstances will permit. We have no good analyses of the soils of England. Several were made by Sir Humphry Davy, but they can only be regarded as loose approximations, since he failed to discover in the most fertile, phosphoric acid, soda, potassa and manganese, which subsequent analyses have shewn to be present in soils of that description, from every region to which the investigation has been extended. In this department of chemistry, great improvement has taken place since the time of Sir Humphry Davy, but the chemists of this country are even yet far behind those of Germany in the analyses of soils.

Tabular view of the analyses of fertile soils.

Liebig has given, in the second edition of his work on the application of chemistry to agriculture, the constituents of a great variety of soils from analyses made by Dr Sprengel, who is celebrated for his skill in this branch of analyses, and for the laborious research by which he has long endeavoured to establish the importance of the inorganic constituents of the soil on the developement of plants.

From these analyses I have selected eight of those of the most fertile soils, and have combined them in a table, in which the relative quantity of a given constituent in each may be seen at one view. The distinctive peculiarities of each soil are separately explained below.

TABLE I. ANALYSIS OF THE MOST FERTILE SOILS.

	I.	II.	III.	IV.	V.	VI.	VII. A.	VII. B.
Silica and siliceous earth	84.543	79.174	64.800	84.021	64.517	79.538	87.143	94.261
Alumina	3.458	3.016	5.700	4.498	4.810	7.306	5.666	1.376
Protoxide of Iron	.....	.....	.....	.....	{ 8.316	{ 5.824	{ 2.220	2.336
Peroxide of Iron	3.488	4.960	6.100	5.120				.....
Peroxide of Manganese	0.560	0.600	0.090	2.080	0.800	1.320	0.360	1.200
Lime	0.319	.....	5.880	0.942	.....	0.619	0.564	0.243
Carbonate of Lime	.....	2.171	.....	.....	9.403	.....	.....	.....
Magnesia	0.740	.....	0.840	1.740	.....	1.024	0.312	0.310
Carbonate of Magnesia	.....	2.226	.....	.....	10.361	.....	.....	.....
Potassa	a trace	0.025	0.210	0.050	0.100	0.200	0.120	{ 0.240
Soda	6.004	6.349	0.393	0.012	0.013	0.024	0.025	
Phosphoric acid	0.260	0.534	0.430	0.482	1.221	1.776	0.060	a trace
Sulphuric acid	0.008	a trace	0.210	0.012	0.009	0.122	0.027	0.034
Carbonic acid	.....	.....	3.920	.....	.....	.....	0.080	.....
Chlorine	0.008	0.005	0.201	0.008	0.003	0.036	0.036	a trace
Humus soluble in alkalies	0.416	0.782	2.540	0.897	.....	1.950	1.304	.....
—— insoluble	{ 0.196	0.158	5.600	{ 0.138	0.447	.....	.....	.....
Nitrogenous matter			1.582		.....	0.236	1.072	.....
Resinous matter	.....	.....	.....	.....	.....	0.025	1.011	.....
Water	.....	.....	1.504	.....	.....	.....	.....	.....
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

I. Is the analysis of a heavy alluvial soil from Norden, taken at the depth of 10 inches, from a field which had received no manure for several years, and had previously produced in succession barley, beans, wheat, and grass; the latter for two years. It is remarkable for the extraordinary quantity of the soda contained in it, which is in combination with silicic acid. The depth of the soil (18 inches) compensates for the small proportion of sulphuric acid, chlorine, and potash, as the roots have thus an extensive range to extract them from.

II. Another heavy alluvial soil from the same locality; depth from which the specimen was taken, 10 inches. The field had received no manure for five years, and had produced since it was manured wheat, rye, and beans; all plentiful crops, and of excellent quality. The presence of so small a portion of gypsum in a soil capable of growing beans is considered by Dr Liebig remarkable, and attributed to the great depth of the soil.

III. A very fertile alluvial soil from Honigpolder. Corn had been grown on it for seventy years without manure, but with occasional fallows. The soil consists of the same constituents, to the depth of from 6 to 12 feet, and when one portion is exhausted fresh layers are brought to the surface. In this and the two preceding, the potassa and soda were chiefly combined with silicic acid. The phosphoric and sulphuric acids were in combination with lime.

IV. The soil of a field celebrated for its large crops of hemp.

V. The surface soil of a very fertile field in Belgium, which had not been manured for twelve years, and has been for the last nine under the following rotation.

1. Wheat.
2. Barley.
3. Potatoes.
4. Winter barley.
5. Clover.
6. Winter barley.
7. Wheat.
8. Oats.
9. Fallow.

The soil had more of a clayey than a loamy character, and was of a very fine grain. The potassa was principally combined with silica. Water extracted from it,

Potash	0.003
Soda	0.013
Lime	0.002
Magnesia	0.012
Sulphuric acid	0.009
Chlorine	0.003

VI. Surface soil of alluvial land in Ohio, North America, remarkable for its great fertility. Much magnetic iron sand is included among the oxide of iron. The phosphoric acid was in combination with lime and oxide of iron. The sulphuric acid was also combined with lime.

VII. A the constituents of the soil, and B those of the subsoil, of a mountainous district in Ohio,

also distinguished for its great fertility. The potassa was chiefly in combination with silica.

Tabular view of soils of medium quality.

I shall now place in one view the analyses of seven soils of medium fertility, which are described as bearing good leguminous crops when manured with gypsum. They were light loams and sands, which in this country would be considered good turnip and barley soils.

TABLE II. ANALYSIS OF SOILS OF MEDIUM QUALITY.

	I.		II.	III.		IV.		V.	VI.	VII.	
	A.	B.		A.	B.	A.	B.			A.	B.
Silica and Siliceous sand	90.221	92.324	95.660	92.980	96.414	94.274	95.146	88.980	88.456	94.430	89.660
Alumina	2.106	2.262	1.586	0.820	1.000	1.560	1.416	2.240	0.650	1.474	0.980
Protoxide of Iron	3.951	0.914	1.616	1.666	1.370	2.496	2.528	3.840	5.608	.....	.....
Peroxide of Iron										2.370	7.616
Peroxide of Manganese	0.960	2.960	0.240	0.188	0.240	0.240	0.320	a trace	0.560	a trace	a trace
Lime	0.539	0.532	0.083	0.748	0.364	0.400	0.297	.....	.....	0.680	0.954
Carbonate of Lime	.....	.....	.....	.....	.....	.....	.....	2.720	1.063	.....	.....
Magnesia	0.730	0.340	0.080	0.168	0.160	0.230	0.221	.....	.....	0.290	0.520
Carbonate of Magnesia	.....	.....	.....	.....	.....	.....	.....	0.600	1.688	.....	.....
Potassa	0.066	0.304	0.030	0.065	0.045	0.102	0.060	0.095	0.040	0.190	0.150
Soda	0.010	a trace	0.220	0.130	0.082				0.012	0.010	
Phosphoric acid	0.367	0.122	0.039	.....	.....	a trace	.....	.....	0.035	.....	.....
Phosphate of Iron	.....	.....	.....	0.246	0.043	.....	.....	.....	.....	.....	.....
Sulphuric acid	a trace	0.010	0.003	a trace	0.005	0.039	0.012	.....	.....	a trace	a trace
Phosphate of Lime	.....	.....	.....	.....	.....	.....	.....	1.510	.....	.....	.....
Gypsum	.....	.....	.....	.....	.....	.....	.....	a trace	a trace	.....	.....
Chlorine	0.100	0.004	a trace	a trace	0.007	0.005	a trace	0.015	0.005	0.015	a trace
Humus soluble in alkalies		.....	0.080	0.764	0.270	0.444	.....	.....	0.550	0.541	0.120
Nitrogenous matter	0.900	.....	.....	2.225	.....	0.210	.....	.....	1.333	.....	.....
Humus insoluble	.....	.....	0.360		.....		.....	.....		.....	.....
Loss	0.140	0.228	.....	.....	.....	.....	.....	.....	.....	.....	.....
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

I. A the surface, and B the subsoil of a fine grained loamy soil from Gandersheim, which is distinguished for its remarkably fine crops of beans, peas, tares, &c. when manured with gypsum.

II. A loamy sand from Brunswick, celebrated for the excellent crops of hops, which it has borne for many years. Hops require considerable quantities of potassa, soda, phosphoric acid, sulphuric acid, lime, and magnesia; none of which abound in this soil, but it is of considerable depth; and hops and all other plants whose roots strike deep into the earth, are enabled to flourish on soils, which on the surface are comparatively poor in the ingredients which they require.

III. A the soil, and B the subsoil, at the depth of 18 inches, of a loamy sand from near Brunswick, which bears good crops of red clover and leguminous plants, when manured with gypsum. Corn is very liable to rust and mildew of the straw on this soil. It contains phosphate of iron, which is also contained in the rust of the straw. Other soils on which the corn was liable to that disease, were analysed, and found to contain phosphate of iron. A portion of such land was removed to another locality, and made into an artificial soil 15 inches deep. The barley and wheat sown upon this were attacked by rust, whilst the barley growing on the rest of the field was free from it.

IV. A the soil, and B the subsoil of a sandy loam from the vicinity of Brunswick, famous for excellent crops of clover, rye, potatoes, and barley;

but the clover must be manured with gypsum. The inferior portions are nearly of the same constitution as the upper, and therefore it is favourable to the growth of deep-rooted plants.

V. The subsoil of a loam from the depth of 18 inches, also near Brunswick. The surface soil bears excellent clover when manured with gypsum, though it only contains a trace of sulphuric acid. At a greater depth than 18 inches the subsoil passes into a marl, containing 20½ per cent. of carbonate of lime.

VI. A very fertile loam from the neighbourhood of Walkenried, on which gypsum exerts a beneficial effect. Most of the soils in the vicinity contain much magnesia, also from ½ to 1 per cent. of gypsum, and the same proportion of phosphoric acid, which render them capable of improving other lands, in which those ingredients are deficient.

VII. A the surface, and B the subsoil at the depth of 18 inches, of a sandy loam near Brunswick, which produces excellent crops of oats and clover; the latter must be manured with gypsum, of which both soil and subsoil contain only a trace. It will be evident, on the inspection of the preceding table, that all the soils on which that substance produces so beneficial an effect are deficient in sulphuric acid.

SECTION IV.

PERMANENT IMPROVEMENT OF SOILS, CONTINUED.

Table exhibiting the analyses of sterile soils—phosphate of iron the cause of rust in corn—results of the three preceding tables combined—practical details of claying a barren sand in Yorkshire—alumina improves a soil by supplying it with potash—proportion of potash contained in different rocks—superior fertility of soils derived from the disintegration of felspathic rocks—china clay manufactured from decomposed felspar—improvement of clayey soils by an admixture of sand—quantities of sea sand used in Cornwall—artificial compost suggested as a substitute for sea sand—action of burnt clay—and of lime on clayey soils.

Tabular view of the analyses of barren soils.

THE third table which follows, contains the analyses of seven soils, selected from the most barren.

	I.		II.		III.	IV.		V.	VI.	VII.	VIII.
	A.	B.	A.	B.		A.	B.				
Silica and siliceous earth	71.504	92.641	51.337	95.204	95.841	95.843	95.180	95.778	85.973	96.721	87.219
Alumina	0.780	1.352	0.528	1.640	0.600	0.600	1.600	0.320	0.320	0.370	4.200
Protoxide of Iron	0.420	2.324	0.398	.....	1.800	1.800	2.200	0.400	0.440	0.480	.....
Peroxide of Iron				1.344							5.200
Peroxide of Manganese	0.220	.....	0.005	0.080	a trace	a trace	a trace	a trace	a trace	a trace	0.310
Lime	0.134	0.929	0.230	0.544	0.038	0.038	0.455	0.286	0.160	0.005	0.320
Magnesia	0.032	0.283	0.040	0.465	0.006	0.006	0.160	0.060	0.240	0.080	0.380
Potash	0.058	0.564	0.010	0.052	0.002	0.005	0.004	a trace	a trace	a trace	0.130
Soda					0.003			0.036	0.012	0.036	0.274
Phosphoric acid	*0.615	0.250	0.066	*0.330	0.198	.....	.....	a trace	a trace	a trace	.....
Phosphate of Iron	.....	.....	.....	.....	.....	0.198	0.400	.....	.....	.....	.....
Sulphuric acid	0.018	1.620	0.022	0.322	0.002	0.002	a trace	a trace	a trace	a trace	0.965
Chlorine	0.014	0.037	0.014	0.019	0.006	0.006	0.001	0.052	0.019	0.058	0.002
Humus soluble in alkalies	9.820	.....	13.210	.....	.....	1.000	.....	0.768	4.636	0.800	1.000
Humus insoluble	14.975	.....	32.100	.....	1.504	0.502	.....	2.300	8.209	1.450	.....
Resinous matters	1.910	.....	2.040	.....	.....	.....	.....	.....	.....	.....	.....
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

* Principally as phosphate of iron.

I. A the analysis of the surface soil of a heath near Brunswick, which is naturally sterile, though abounding in humus. It produces good crops, when manured with lime, marl, cow-dung, or the ashes of the heaths which grow upon it. B is an analysis of the ashes of the heath before its conversion into arable land. The increase in some of the constituents, such as sulphuric acid, potash, soda, magnesia, oxide of iron, oxide of manganese, and alumina, which takes place after burning in this and the following case, is ascribed to their having been confined in the vegetable remains in such a manner as to prevent their being exhibited by analysis before burning.

II. The analysis of a heath near Brunswick, made before any crops had been raised on it. The first was corn, which was attacked with rust, even on those portions which were respectively manured with lime, marl, potassa, wood ashes, and bone dust, ashes of the heath, and ammonia. The tendency to this disease still manifests itself after the third year; but it is considered probable that longer exposure to the air, by converting the protoxide of iron into the peroxide, will give greater power to lime to decompose the phosphoric acid.

III. A sandy soil from the vicinity of Brunswick, particularly sterile, though containing as much humus as some of the most fertile, but the inorganic ingredients are present in very small quantity. It has been much improved by manuring it with marl, containing 24 per cent. of lime, together with magnesia, manganese, potassa, soda, gypsum, and common salt.

IV. A the soil, and B the subsoil of an eminently

barren sand, containing the average quantity of humus, but poor in lime, magnesia, potash, and gypsum. White clover would not grow on it, till manured with marl containing those substances, when the crops of that plant became luxuriant.

V. A barren heath soil from Aurich in Ostfriesland.

VI. VII. Sandy soils also sterile though containing humus.

VIII. The clayey subsoil of a moor, which after being burned is used to manure V. VI. and VII. These ashes it is evident impart the lime, magnesia, potash, and soda, which were deficient in the soil. The two last are principally combined with silicic acid; the sulphuric acid, with lime, magnesia, and potash.

Table combining the results of the preceding tables.

I shall now exhibit in one table the results of the three preceding tables; shewing the greatest, least, and average quantity of each constituent contained in the three varieties of soil represented by the above tables.

TABLE IV.

THE RESULTS OF THE THREE PRECEDING TABLES COMBINED.

	BEST SOILS.			MEDIUM SOILS.			BARREN SOILS.		
	Highest.	Lowest.	Mean.*	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.
Silica and siliceous sand	87.143	64.517	77.676	95.660	88.456	92.143	96.274	51.337	84.650
Alumina	7.306	3.016	4.454	2.240	0.650	1.490	0.780	0.320	0.502
Protoxide and Peroxide of Iron	8.316	2.220	5.146	5.608	1.616	3.078	1.800	0.398	0.818
Peroxide of Manganese	2.080	0.090	0.830	0.960	a trace	0.312	0.220	a trace	0.032
Lime	5.880	0.319	2.120	1.531	0.083	0.592	0.286	0.005	0.127
Magnesia	5.008	0.312	1.534	0.730	0.080	0.362	0.240	0.006	0.066
Potassa and Soda	†0.393	0.012	0.239	0.250	0.052	0.138	0.058	0.005	0.023
Phosphoric acid	1.776	0.060	0.680	0.367	a trace	0.063	0.615	0.066	0.125
Sulphuric acid	0.210	0.008	0.055	0.039	a trace	0.006	0.018	0.002	0.006
Chlorine	0.201	0.005	0.042	0.100	a trace	0.020	0.058	0.006	0.024
Organic matter	9.722	0.450	2.474	2.989	0.440	1.061	45.310	0.502	12.000

* Obtained by adding the results of all the analyses of the *surface soil*, and dividing by the number of analyses.

† Nos. I. and II. are omitted, because of the very extraordinary quantity of Soda contained in them.

From this table it appears that the most fertile soils contain on an average full 77 per cent. of silica, and that the organic matter varies from about $\frac{1}{2}$ per cent. to more than 9 per cent., while in the most barren it sometimes amounts to as much as 45 per cent., the mean being 12 per cent. Can any thing afford a more convincing proof, that humus is not the cause of fertility, but that it depends upon the amount of those inorganic substances, which, though present in but small quantities even in the most fertile, diminish with the decreasing productiveness of the soil?

The inorganic substances which appear in the next proportion to silica are alumina and peroxide of iron; the first ranges in the most fertile soils from 3 to more than 7; the latter from 5 to 8 per cent. The proportion of lime in the most fertile soils is not on the average much above 2, nor of magnesia above $1\frac{1}{2}$ per cent.; while the proportion of the alkalies and of sulphuric and phosphoric acids, is expressed by such small fractions as $\frac{239}{1000}$, $\frac{690}{1000}$ and $\frac{55}{1000}$ per cent., and as we descend in the scale of fertility, a corresponding decrease takes place in the proportion of all those substances, as will be evident from the mere inspection of the table. Can any thing more strongly point out that the improvement of inferior soils is to be sought, in the addition of those inorganic substances in which they are deficient, so as to bring their chemical composition as near as circumstances will permit, up to the standard of soils of the best description as regards productiveness, the facility with which they may be worked in all seasons, and their adaptation to the growth not only of corn, but of crops necessary for the subsistence of cattle?

Suppose, for instance, the owner (or the tenant

under a long lease) of a soil capable in its natural state of producing only indifferent crops of oats, barley and rye, desirous of rendering it fit for the growth of wheat; this may be done (when clay or marl are found beneath the surface, or within a convenient distance) by laying it on in quantities varying from 100 to 200 cubic yards per acre. We will suppose the proportion of alumina naturally existing in the soil to be ½ per cent., viz. the mean of that contained in the inferior soils of the third table, and the lowest amount contained in the soils of medium quality in the second table. Now since an acre contains 43,560 square feet, there will be 1613 cubic yards in an acre of soil one foot in depth, and taking a cubic yard in a medium state of moisture at a ton, it will require rather more than 48 tons of alumina to raise the proportion contained in the soil 3 per cent. But clay in the purest form in which it occurs, contains rarely more than half its weight of alumina. It would therefore require 96 tons of pipe clay, or about 200 tons of marl, containing

Alumina	25	per cent.
Carbonate of lime	20	...
Carbonate of magnesia.....	10	...
Silica, oxide of iron and water	45	...
	100	

and 200 tons of such marl would, at the same time, introduce into the soil 40 tons of carbonate of lime and 20 tons of carbonate of magnesia, answering to about 22½ tons of lime and 9½ tons of magnesia to the acre, which added to the quantities of those earths previously existing in the land, would bring it up, in these respects, to the standard of some of the best soils. Should this

marl contain, as is sometimes the case, $\frac{1}{2}-1$ per cent. of sulphate, and $\frac{1}{2}-1$ per cent. of phosphate of lime, its value as an improver of the soil will be the greater.

Improvement of land by clay in Yorkshire.

There is nothing visionary in this mode of improving land; it has long been practised, not only in Norfolk as was before observed, with the happiest success, but in several other counties.

In the second volume of the Journal of the Agricultural Society, Mr Lenton, of Sheriff Hutton, near York, has described in detail the cost and results of this transposition and admixture of soils, as practised by himself for many years. The land thus clayed was a sand, so barren that it had never been cultivated to profit, either by landlord or tenant; about one fifth was entirely out of cultivation and overgrown with gorse and ling. The substratum was a white sand, varying in depth from one to four feet, beneath this sand was a yellowish clay about a foot thick, and underneath that a rich marl about eighteen feet deep. The land being wet, was first drained with tile drains two feet deep, and nine yards asunder. The best time for laying the marl on, was found to be July and August, while the land was under seeds, (after being brought under the four-course system), because the carriage of the large quantity of clay required, was easier when the land was under seeds than on a fallow, and the injury to the land by heavy cartage, and the loss occasioned by having a bare fallow instead of turnips were thus avoided. The quantity laid on varied from 100 to 200 cubic yards, according to the quality of the soil.

When sufficiently clayed to produce wheat after seeds, —a point described as requiring close attention,—it was found to answer effectually for every other crop. To have carried the claying beyond this point, would not only have incurred unnecessary expense, but would have injured the land for barley, and for feeding off the turnip crop on the land. How this just medium was attained, and how, in the first instance, it was known what quantity of clay would be sufficient to make the land produce wheat after seeds, we are not informed. It was probably the result of experiment during several years, and might have been calculated beforehand from an accurate analysis of the soil and the marl with which it was to be dressed.

The total expense is thus stated, taking 150 cubic yards per acre as the average quantity laid on.

	£.	s.	d.
Digging and spreading 150 yards, at 4½*d.* per yard	2	16	3
Four horses four days, at 2*s.* 6*d.* = 10*s.* per day	2	0	0
Driver four days, at 2*s.* 6*d.*	0	10	0
Wear and tear and other expenses	0	3	0
	£5	9	3

about seven shillings an acre of this cost was saved, during the latter part of the operation, by using a horse windlass for drawing the marl out of the pit, and thus employing only three instead of four horses. This reduced the expense to £5. 2*s.* 3*d.* per acre.

Before being clayed, the land would not produce more than 3½ quarters of oats per acre. The rotation of crops was very irregular. To the oats generally

succeeded a fallow, sometimes for turnips, sometimes for rye; the former generally failing from the springy nature of the land before being drained. Barley, with which seeds were sown, followed the turnips; and the land then remained in pasture for four or five years; the utmost produce in four years could not be stated at more than

	£.	s.	d.
1st year turnips	4	0	0
2nd . . . barley or rye	4	0	0
3rd . . . seeds in pasture	2	12	0
4th . . . oats, barley, or rye	3	15	0
	£14	7	0

The land after being clayed is now cultivated on the four-course rotation, and the produce is stated to be the following:

	£.	s.	d.
1st year, wheat, 24 bushels at 56*s.* per qr.	8	8	0
2nd . . . fallow turnips	4	15	0
3rd . . . oats, 52 bushels at 23*s.* per qr.	7	9	6
4th . . . seeds depastured	4	4	0
	24	16	6
Produce before marling	14	7	0
	£10	9	6

This increased produce however, cannot all be ascribed to the marling alone, as the draining must have contributed to it, and therefore its cost should be added to that of marling, stated at £5. 2*s.* 3*d.* This improvement was made at the charge of the landlord, the tenant paying him an additional rent of 4 per cent. on the capital expended.

As clay contains in general much oxide of iron, few kinds of clay or marl can be laid on land in the above quantities, without adding to the amount of oxide of iron contained in it, the proportion of which, it will be seen by the last table, is always greatest in soils of the best quality.

Since alumina, as Liebig tells us, is rarely taken up by plants, and oxide of iron is only found in their excrementitious matter, it may appear strange that a soil should be improved by their presence. They exert however, a two-fold influence, by absorbing ammonia from the atmosphere, which is separated by every shower and conveyed in solution to the roots, and by forming salts of ammonia, in which that substance acts as a base.

Alumina increases the fertility of soils by supplying potassa.

Alumina increases the fertility of a soil in another most important manner, by supplying plants with that potash which is found in different proportions in the ashes of most cultivated plants, particularly the corn and grass tribe, and above all in wheat. Potash is contained in clays and all aluminous soils, nor is this to be wondered at, when we consider their origin. All aluminous soils have been produced by the disintegration or crumbling of rocks, composed of the minerals called felspar, zeolite, albite, and mica, which contain either potassa or soda, or both. Felspar, the most abundant of these minerals, yields $17\frac{3}{4}$ per cent. of potassa, albite 11.43 per cent. of soda, and zeolite contains 13 to 16 per cent. of soda and potash together. The rock called basalt, contains from $\frac{1}{4}$ to 3 per cent. of potassa, and from 5 to 7 per cent. of soda.

Clay slate from 2.75 to 3.31 per cent. of potassa, and loam from 1½ to 4 per cent. of potassa. From these data Liebig has calculated the quantity of potassa contained in a layer of soil 20 inches deep, formed by the decomposition of each of the rocks of which it forms a constituent. His calculations are made for the Hessian acre (26,910 square feet), which reduced to English measure will give the following quantities.

Proportion of potassa contained in different rocks.

Felspar contains ..... 2,711,371 lbs. of potassa.
Clinkstone .... 356,120 to 712,243 .....
Basalt ..... 85,402 to 133,707 .....
Clay-slate ..... 178,060 to 356,120 .....

One thousandth part of potassa contained in a soil only 20 inches deep, is sufficient for the consumption of all the pines growing on it during a century, and a cubic foot of potassa is sufficient to supply those growing on an area of 26,910 square feet for five years. Thousands of years are required for the disintegration of the surface of rocks containing potassa. Water, charged with carbonic acid, decomposes the felspar and dissolves a part of the alkaline carbonates; and plants, by producing carbonic acid during their decay, combine with the action of the atmosphere in effecting the disintegration of such rocks. The solution of the alkalies contained in the magazine thus formed, proceeds by a process equally slow. From the composition of the water of rivers and springs, we see how small a quantity rain water is able to extract from the soil; and that a portion of the alkalies washed into the sea, is returned by evaporation is evident, from the fact, that the softest river water contains a small proportion of common salt.

Part of the alkalies dissolved by rain water is taken up in combination with acids by the roots of plants, is retained in their substance, and returned to the soil by their decay.

Fertility of soils resulting from decomposed felspathic rocks.

The superior fertility, under equal conditions with respect to elevation and exposure of a soil derived from the disintegration of rocks containing potash, is illustrated very strikingly by several instances mentioned by Mr De la Beche, in his Geological Survey of Devon and Cornwall. The mineral structure of the grauwacke, or slate series of that country, is extremely variable: where hard sandstones prevail, not easily decomposed, they produce but a sterile soil; one of greater fertility is derived from the disintegration of the fine argillaceous slates, which however produce a wet clay when the natural drainage is not good. In the north, the trappean rocks which are chiefly compounds of felspar and hornblende, afford the most fertile soils when decomposed to a sufficient depth, of any in the district, particularly when mixed with some calcareous matter, as is frequently the case. When much decomposed, they are applied as manure to other land, and always with great benefit. The general barren character of the serpentine of the Lizard contrasts strongly with the soil on the adjoining diallage and sienite, which are among the most fertile of the district. "It affords, indeed, a good example of the unequal decomposition of a rock, so that while it is so much disintegrated in places, that marl pits may be formed, and the decomposed rock taken away for manure, in others, hard blocks are scattered over the

ground, or rise in tors through it; and it also exhibits an instance of the fertility of a soil chiefly derived from the decomposition of hornblende, or diallage and felspar, the crystallization being large grained." The hornblende slate of the Lizard is also extremely fertile; some land upon that rock was, after being inclosed, frequently cropped with barley and wheat without being manured, and yielded well under this management for many years. It will be seen in Table I. that the soils from Ohio contained much magnetic iron-sand, and, as that is a very common constituent of trappean or basaltic rocks, it is probable that a large portion of the materials of that soil had been derived from the decomposition of such rocks. Trappean and volcanic rocks are closely allied, if not identical in mineral composition, and decomposed lavas afford soils of the most fertile character. Volcanic ashes, when exposed for a time to the influence of the atmosphere, produce a most luxuriant vegetation, though they do not contain a trace of organic matter. The land in the vicinity of Vesuvius is of this description; corn has been grown on it for centuries (without any portion of the produce being returned to the soil), by the rude process of cultivating the land once in three years, and leaving it to natural pasture during two. Its fertility arises from the potassa, which is contained in the lava of which it is composed, and of which a fresh portion, sufficient for the support of another corn-crop, is rendered soluble during this interval of rest.

It is remarked by Mr De la Beche, that the relative fertility of the granitic soils of Cornwall appears to depend, under equal conditions of elevation and exposure, on the abundance and easily decomposable nature of the felspar contained in the sub-jacent rock.

Those parts of the Hensborough and St Austell granite which contain much of the mineral called schorl, are often sterile: a large proportion of mica in granite exerts an unfavourable effect on the soil derived from it, while the iron of others forms a useful element. A large part of the skirts of Dartmoor is poor land, but is much improved where the decomposed drift from the trappean rocks has mingled with it. The scrapings of roads, metalled with broken hornblende, syenitic and basaltic rocks, which are now used on the roads in the metropolitan district, and in a considerable portion of the new red sandstone of Cheshire and Lancashire, are capable of improving sandy soils, by the addition of aluminous earth and oxide of iron.

China Clay manufactured from decomposed Felspar.

From the decomposing granites of Cornwall a very pure and white china clay is manufactured. The finer particles of the felspar are separated from the quartz and mica, by exposing it on an inclined plane to a fall of a few feet of water, which washes it down a trench communicating with catch-pits; in these the impurities and coarser parts are deposited, and the finely-divided felspathic matter is allowed to settle in a tank beyond them. The water having been withdrawn after a time, the clay, when it has attained a certain consistency, is divided into masses containing about a cubic foot each, and removed to covered sheds, where the drying process is completed. The clay prepared thus with great care that it may contain no impurities, which would deteriorate the colour of the china, is sold at about £1. 2*s.* the ton. Perhaps in some situations, where decomposed granite and streams of water are at com-

mand, fine felspathic matter might be conveyed, suspended in water, by a somewhat similar process, over the neighbouring lands deficient in potash, the fertility of which there can be no doubt that it would greatly improve, if the process was not too expensive. Ordinary pipe-clay, which is sold at the pit on the average at £1. 2*s*., is nothing more than this finely divided felspar, which has been deposited by natural processes at some remote period in the bed of a lake now laid dry.

Improvement of Clays by an admixture of Sand.

We have hitherto considered the permanent improvement of light lands by the addition of alumina; but clays may, in a similar manner, be improved by the addition of other earths. Chalk is extensively used for this purpose in Essex; limestone gravel in Ireland. The operation of these substances is partly chemical, partly mechanical. They add lime to a soil deficient in it; and they increase its porosity, rendering it more pervious to the roots and to moisture, and more easily worked. Ordinary sand, though less frequently used, would promote the latter object. We have seen how large a portion of silica the most fertile soils contain. On many parts of the coast, sea and blown sand are extensively employed as a manure;—nowhere, perhaps, so extensively as in Cornwall and Devonshire, where it is not only used on the coast, but is conveyed by carts and canals into all parts of the interior.

Quantity of Sea-sand used as Manure in Cornwall.

Mr De la Beche, in the work before mentioned, estimates that 7,000,000 cubic feet of sand are thus annually collected and distributed over those counties. The sands considered worth removal at this expense

for agricultural purposes, contain, according to Dr Paris, from 60 to 65 per cent of carbonate of lime, consisting of fragments of shells and corals; and he suggests that, though the beneficial effects of this manure unquestionably depend on the presence of this calcareous matter, yet the sea-salt with which it is impregnated, contributes largely to its fertilizing powers; and he adduces as confirmatory of this opinion, the fact, that the farmers frequently send several miles to Padstow Harbour for the same sort of sand which is drifted by the wind close to them.

Analysis of Sea-water.

The water of the North sea contains, according to an analysis of M^c^Clemm cited by Liebig,

Chloride of sodium	26.84
Cholride of magnesium	2.42
Sulphate of magnesia	2.06
Chloride of potassium	1.35
Sulphate of lime	1.20

besides inappreciable quantities of carbonate of lime, magnesia, iron, manganese, phosphate of lime, iodides and bromides, silica, sulphuretted hydrogen, and organic matter.

An artificial compost suggested as a substitute for Sea-sand.

Now if the fertilizing properties of sea-sand containing from 60 to 65 of carbonate of lime, be due to the small portion of the above salts which it contains, an artificial compost might very easily be prepared by saturating a mixture of sand and finely

comminuted carbonate of lime with a solution of those salts of the same strength as sea-water; and this mixture might often be prepared on the spot at a much less cost than that at which sea-sand can be procured.

Action of burnt Clay and of Lime on clayey soils.

The beneficial influence which burnt clay exerts on stiff soils, and which has been considered so inexplicable, has been already noticed; its action is partly mechanical by opening the soil, and rendering it more pervious to moisture, and partly chemical, arising out of the property which alumina and oxide of iron possess of absorbing ammonia, and forming compounds with it.

The action of burnt lime on clay is purely chemical; such soils disintegrate and liberate their potash with much less facility and rapidity than siliceous soils; and the lime renders it more soluble. This has been ascertained by mixing an equal quantity of burnt lime, adding water, and letting the mixture stand for some time, when the water was found to contain an appreciable quantity of potash.

Clayey soils also derive benefit from the chemical action of lime in another way. They frequently contain proto-sulphuret of iron, which decomposes by exposure to the air into sulphate of the protoxide of iron, a salt which exerts, as was before stated, an injurious effect on vegetation. Lime decomposes this salt, forming with it sulphate of lime, and liberating the protoxide of iron, which on exposure to the air is converted into the peroxide, and then becomes a medium for indirectly communicating to the roots ammonia absorbed by it from the atmosphere.

SECTION V.

MANURES.

Constituents of farm-yard manure—of the straw—of the solid excrements—of the urine—loss of ammonia during the heating of farm-yard manure—use of liquid manure in Belgium—mode of preparation—in Switzerland—mode of application—to what soils and crops—in what quantity.

Farm-yard Dung.

We will now proceed to the consideration of those manures which are used with the design of restoring to the soil substances of which previous crops had deprived it, rather than for the purpose of effecting its permanent improvement by the addition of elements in which it is deficient, or by decomposing substances which exert an injurious effect upon vegetation.

Of these manures the most important and the most generally used is farm-yard dung. Since it consists of vegetable remains saturated with urine, and mixed with the solid excrements of cattle, the prevalent opinion is by no means surprising that plants require for their nutriment matter which has undergone previous preparation, either by having entered into the structure of plants, or having passed through the bodies of animals. An analysis of the constituents of farm-yard manure, and the knowledge that plants receive nothing from the soil except in a state of solution, completely overthrow this assumption,

and shew that its fertilizing powers are due to the presence of the same acids and alkalies which occur most abundantly in the most fertile soils, and are found in the ashes of all plants, though in different proportions in different tribes of them; and thus we arrive by another road at the same conclusion, that those inorganic substances, the acids, alkalies, and metallic oxides, are essential for their perfect developement.

Constituents of the Straw contained in it.

Let us begin with an examination of the straw. Straw dried at a temperature of 212° Fahrenheit yields

Carbon . . .	46.37 per cent.
Hydrogen . .	5.68
Oxygen . . .	43.93
Ashes	4.02
	100.00

It consists therefore of 96 per cent. of matter identical in composition with woody fibre, and convertible like it into humus by decay. The beneficial effects of humus, it has been already shewn, consist in its entering, during the process of decay, into combination with the oxygen of the atmosphere, and thus furnishing a supply of carbonic acid to the roots before the leaves of the young plants are sufficiently developed to decompose that of the atmosphere, from which plants derive their chief supply of carbon. A liberal supply of carbonic acid to the young plant promotes a vigorous growth of leaves, and increases the power of absorbing it from the atmosphere at a

later period; and so far tends to increase the crop. But the woody fibre, instead of being putrefied in the dung-heap, might be converted into charcoal; and charcoal, it has been shewn, may be made to supply the place of humus by absorbing carbonic acid and imparting it to the roots.

The proportion of ashes varies in the straw of different kinds of grain; that of wheat yields 15.5 (Davy), that of barley 8.54, that of oats 4.42 per cent. These ashes consist principally of silicate of potash, and are equally returned to the soil whether in the form of ashes or of decayed straw. In some parts of the Grand Duchy of Hesse, where fuel is dear, straw is used for the purpose of heating ovens; and the ashes, which are carefully collected and sold at a high price, are found to be the best manure for wheat and the different kinds of corn, though of no value for the growth of other crops, such as potatoes, peas, and clover. The benefit which corn derives from the putrefied straw might therefore be communicated by means of an artificial compost, consisting of charcoal and silicate of potash—the *soluble glass* of commerce. But corn requires other substances besides carbon and silicate of potash; it must have nitrogen for the gluten and vegetable albumen, and phosphates of lime and magnesia for other constituents of the grain. These are contained in the solid and fluid excrements, but more abundantly in the latter.

Constituents of the Solid Excrements.

We will first consider the composition of the solid excrements. This varies with the species of animal and with the nature of the food. The following are

the constituents of the dung of the cow. One hundred parts of the fresh excrements consist of

Nitrogen	0.506
Carbon	6.204
Hydrogen . . .	0.824
Oxygen	4.818
Ashes	1.748
Water	85.900
	100.000

The ashes consist principally of potash. All the potash contained in the hay or other food of cattle is discharged in the excrements. In 25 lbs. of hay a beast consumes $\frac{1}{4}$ of a pound of nitrogen, which is the quantity contained in $8\frac{5}{10}$ lbs. of flesh. The nitrogen assimilated and not converted into flesh or milk, is discharged in the dung and urine. The quantity of nitrogen contained in the dung barely exceeds, as will be seen by the above analysis, $\frac{1}{2}$ per cent.; but as hay contains 1 per cent., 50 lbs. of hay ought to produce the same effect as 100 lbs. of fresh cow-dung, if the value of the latter depended on its nitrogen.

One hundred parts of horse-dung, dried at a temperature of 212° Fahr., leave from 25 to 31 parts of solid matter, and consequently contained from 69 to 75 parts of water; when treated with water, about 3 to $3\frac{1}{2}$ per cent. is dissolved; the solution containing phosphate of magnesia, and salts of soda, with a small quantity of organic matters. Alcohol extracts from the undissolved portion a resinous substance, possessing the characters of partially changed gall;

the residue burns without any smell, and possesses the properties of sawdust, from which all soluble matter has been extracted. One hundred parts of the dung thus dried, yield from 10 to 27 per cent. of salts and earthy matters, according to the nature of the food.

With from 3,220 to 4,000 lbs. of fresh horse-dung Liebig calculates that we therefore lay on a field 2,220 to 3,000 lbs. of water, 730 to 270 lbs. of vegetable matter and altered gall, and from 100 to 270 lbs. of salts and inorganic substances, consisting principally of the phosphates of lime and magnesia, carbonate of lime, and silicate of potassa; the first derived chiefly from the oats and hay with which the horse had been fed, the latter from the straw used as litter; and the same quantity of these inorganic substances is contained in 6,000 lbs. of hay, or 8,300 lbs. of oats.

Constituents of the Liquid Excrements.

Plants in a state of nature derive sufficient nitrogen for their wants from the ammonia contained in rain-water. In a state of cultivation, the object of which is the extraordinary developement of the most useful parts, the seeds or roots, they require larger supplies of nitrogen, which must be furnished by means of manures. The proportion of nitrogen in cow-dung does not exceed, as we have seen, $\frac{1}{2}$ per cent.; in human excrements, which contain the largest proportion, it varies from $1\frac{1}{2}$ to 5 per cent. It is to the urine with which farm-yard manure is saturated that we must look for supplies of nitrogen. Human urine, which is the richest in it of all, contains—

Urea	30.10
Free lactic acid, lactate of ammonia, and animal matter not separable from them	17.14
Uric acid	1.00
Mucus of the bladder	0.32
Sulphate of potash	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Phosphate of ammonia	1.65
Chloride of sodium	4.45
Muriate of ammonia	1.50
Phosphate of magnesia and lime	1.00
Siliceous earth	0.03
Water	933.00
	1000.00

It must be to its ammonia and ammoniacal salts that urine owes its fertilizing powers; for, after deducting the urea, lactate of ammonia, free lactic acid, phosphate and muriate of ammonia, there remains only 1 per cent. of solid matter consisting of inorganic salts; which must have the same effect on the land, whether dissolved in water or urine.

The urine of horses is less rich in nitrogen than that of man, containing only 5 per cent. of solid matter, of which only 0.7 is urea, whilst human urine contains four times as much.

Loss of Ammonia during the putrefaction of Farm-yard Manure.

By the spontaneous putrefaction of urine, which it undergoes in the dung-heap during the process of heating, all the urea in combination with lactic acid is converted into lactate of ammonia, and all the free urea

into carbonate of ammonia; and as the latter salt is extremely volatile, a large portion of ammonia is lost during the fermentation and turning of the dung-heap, and whilst the manure is lying on the land before it is ploughed in. It is in the shape of ammonia that plants receive the nitrogen, which is essential to their complete developement. However abundantly humus, carbonic acid, and other substances may be supplied, a plant cannot attain its full developement without plenty of nitrogen: a herb may be formed, but no grain; even sugar and starch may be formed, but no gluten. If, however, sufficient nitrogen be administered, we furnish a plant with the power of attracting carbonic acid from the atmosphere, and of fixing in its organs the amount of carbon requisite for its nutrition. The most economical mode, therefore, of applying the urine of our stables and cattle-sheds, is an object of the utmost importance to the farmer. We have seen that during the heating of a dung-heap a large portion of nitrogen escapes in the form of carbonate of ammonia. Any person may easily convince himself of this by placing on a dung-heap a saucer containing hydrochloric acid, (muriatic acid or spirits of salts,) when dense white fumes of hydrochlorate of ammonia (sal ammoniac) will immediately surround it, and, after a time, crystals of that salt will be found in the saucer. The volatile nature of carbonate of ammonia may also be known by exposing a given weight of it, in its solid state, to a dry atmosphere, and weighing it again after the lapse of a few days. At the same time, urine cannot be used fresh. Its complete putrefaction is necessary, because the first step in the decomposition of the urea is its conversion into caustic ammonia, which is injurious to vegetation. By expo-

sure to the atmosphere this caustic ammonia acquires carbonic acid, and is rendered mild, and brought into a form capable of affording nutriment to plants; but at the same time a large portion is lost, owing to its volatile nature. How are these difficulties to be avoided?

Liquid Manures.

The application of the urine in a separate form, which has been so long practised in Belgium, Germany, and Switzerland, to say nothing of China, is strongly urged by Liebig. The adoption of the practice in this country is attended, however, with some inconveniences, arising out of the large size of our farms, the complete alteration which it would require in the arrangement of farm-buildings, and the expense which would be incurred in the construction of tanks and drains; added to which, without careful management, a large portion of ammonia may be lost even in this mode of using the urine, or it may be used in too large quantities, or in too fresh a state, and therefore prove injurious to the growing crops. To those who may be disposed to try the system, an account of the manner of preparing and applying liquid manure in those countries where it is so extensively used, must be acceptable. The following outline is taken from an article on the Agriculture of the Netherlands, by Rham, and from another on Animal Manures, by Sprengel, both in the second volume of the Journal of the Agricultural Society.

There are two ways of applying liquid manure. It may be either used alone, the litter and solid excrements being collected and applied as in this country; or the solid excrements may be dissolved in the urine,

and the mixture putrefied with the addition of large quantity of water. The first method is practised in Belgium, the latter in Switzerland and the Black Forest.

Mode of preparing Liquid Manure in Belgium.

In Belgium every farm has, either under or near to the cowhouse, one or more tanks into which the urine of the animals flows, together with the water used in washing the floor of the stables and cattle-sheds.

The tanks are sunk below the level of the ground, their sides built of brick laid in cement, to prevent loss by filtration. In large distilleries where many beasts are kept, there are large oblong tanks divided into chambers, so that a succession of liquor may be kept of the proper age for use. The dimensions of these chambers are 8 feet square, by 6 or 8 deep; they are sometimes vaulted, but more frequently covered with boards. On a farm of 30 or 40 acres, the tank is generally 20 feet long, 12 wide, and 6 deep, with a partition in the middle, and arched over, leaving a small round opening for the pump; and another (covered by a trap-door) sufficiently large to admit a man for the purpose of clearing the tank of the sediment which accumulates at the bottom. The tank is either near the entrance of the cow-house, or immediately behind it, sometimes under it like a cellar; but this is apt to communicate a bad smell to the cowhouse. The farmers, besides saving all the urine they can collect, purchase liquid manure in considerable quantities. Every village increases the supply, each house being furnished with a small tank

or tub, in which is collected all the liquid which can in any way be useful, such as soapsuds, the washings of dishes, chamber-lye, &c., till the farmer or contractor comes (once a week) with his cart or tub to remove it. This, mixed with the contents of privies, which are frequently emptied, he keeps either for use or sale. There are dealers who have large tanks near rivers and canals, where they keep great quantities in store, in tanks, having in one corner a graduated scale by which the quantity of liquid in the tank may be ascertained. To the tanks of these dealers the farmers repair in the seed-time of autumn and spring with their carts and tubs, purchasing it at the rate of 2*s*. 6*d*. the hogshead.

In the farm-yard the liquid contained in the tank is mixed with an equal quantity of water, not only to cleanse the stables, but to improve the manure; for the addition of this water, before the putrefaction of the urine, has been found by experience to be very advantageous; and the reason of it is this: Water absorbs only a certain quantity of ammoniacal gas; and this will be greater the less of other substances it holds in solution. If therefore the urine be mixed with an equal bulk of water, it absorbs more than as much again of ammonia, and is also able to retain more carbonic acid, which is partly given out during putrefaction, partly absorbed from the atmosphere. The caustic ammonia generated during the putrefaction of the urine is thus converted into its carbonate, which, though still volatile, is far less so than ammonia itself.

Sprengel found, by experiment, that from 100,000lbs. of urine diluted with an equal quantity of water, he obtained in consequence of this dilution 1,135 lbs. of

ammonia, equal to 936 lbs. of nitrogen, more than from undiluted urine. He takes the annual quantity of urine produced by a cow at 15,000 lbs., and supposing that it all reaches the tank, he calculates that by putrefying it without the addition of water, 162 lbs. of ammonia, worth in Germany £2., is lost, whilst the cost of distributing the additional 15,000 lbs. of water over the land is 8*s*.

With respect to the time required for the proper putrefaction of the urine, some farmers reckon that it should remain in the tank six months, but by the end of that time it will have lost much of its ammonia. In Sprengel's experiments all the urea was not decomposed at the end of four weeks; before the expiration of six or seven weeks the ammonia is still in a caustic state, and injurious to vegetation; when left in the tank for six months a large portion of the carbonate of ammonia has evaporated, and it has therefore lost much of its manuring powers, as much, perhaps, as by our method of putrefying it in the dung-heap. If urine has not been mixed with water, and contains, as it generally does, a certain portion of solid excrement, it is considered a sign of having acquired a proper maturity in the tank, when no scum rises on the surface on stirring the liquor. This is indeed a proof that it no longer contains caustic ammonia, and can be applied without injury to growing crops; for the scum or bubbles are occasioned by carbonic acid, which cannot escape till all the ammonia present is saturated with it. But before the undiluted urine can have reached this state a vast amount of ammonia must have been lost.

The time required to effect the decomposition of the urea, and the saturation of the resulting ammonia

with carbonic acid, varies with the season. Five or six weeks are considered sufficient in the summer, and eight or nine in the winter; but no fixed rules can be laid down, as the rate of putrefaction depends on the temperature of the air. The absence of caustic ammonia and urea, on which depends its ripeness, can only be known by chemical investigation. If on adding a small quantity of sulphuric acid there arises after a few seconds a gentle effervescence, it may be considered that the ammonia is saturated with carbonic acid; but if effervescence does not take place till after the addition of a further quantity of acid, caustic ammonia must be considered as still present, because the sulphuric acid must first saturate the free ammonia before it can act upon the carbonate, to the decomposition of which the effervesence is due. The quantity of sulphuric acid required to effect effervescence will afford an indication of the amount of ammonia still remaining in the urine uncombined with carbonic acid. The addition of water to the urine before putrefaction prevents, as was before said, the escape of free ammonia, and destroys its caustic properties by converting it into the carbonate; but carbonate of ammonia is still volatile, though less so than ammonia.

The most effectual mode of fixing the ammonia, is to convert it into the sulphate, which is not volatile. In order to do this, sulphuric acid, or some cheap sulphate, as sulphate of iron (green vitriol), or sulphate of lime (gypsum), should be added. Both are occasionally used by the farmers on the continent, who have found that they improve the quality of the manure, without knowing the reason.

If we calculate that a cow produces in the course

of the year 15,000 lbs. of urine, and that by the putrefaction of this urine in tanks, without mixing it with water, 162 lbs. of ammonia escapes, this might be converted into sulphate of ammonia by means of 373 lbs. of sulphuric acid, which at 12*s.* the cwt. for which it may be purchased in this country, would cost nearly £2. This would produce more than 4½ cwt. of sulphate of ammonia, worth at 25*s.* the cwt. £5. 12*s.* 0*d.* The fixation of this 162 lbs. of ammonia lost during the ordinary process of putrefaction, might also be effected by means of 5 or 6 cwt. of gypsum at 2*s.* 3*d.* per cwt. or 7 cwt. of sulphate of iron, at 7*s.* 6*d.* per cwt. There is, however, another disadvantage attending the use of sulphate of iron besides its cost, viz. that if used in larger quantities than the ammonia present will decompose, it exerts an injurious effect on the growing crops. The protoxide of iron, also resulting from the decomposition of the sulphate requires exposure to the air for some time, to effect its conversion into the peroxide. It then adds to the fertility of a soil by absorbing ammonia from the atmosphere.*

Mode of preparing Liquid Manure in Switzerland.

In some parts of Switzerland, Germany, and Holland, the solid as well as liquid excrements are mixed with large quantities of water in trenches or tanks, and the liquid compound, after putrefaction, is applied as manure to arable and meadow-land, under the name of *gülle*. The preparation of it takes place in tanks either adjoining the cowhouse, or in the fields to which the excrements are conveyed, and there

* An excess of gypsum on the contrary is not injurious.

mixed with water conducted from the neighbouring springs, by which much labour in the carriage of water is saved.

In the former case, the floor of the cowshed has a slight inclination towards a drain or trench, 1½ feet wide and 2 feet deep, leading into a tank outside the shed, 6 or 8 feet every way, and covered with a lid. The drain being half filled with water, the urine runs into it, and the animals stand with their hind-legs close to the drain, so that a large portion of the solid excrements are likewise dropped into it. The rest is raked in once or twice a day, and the floor well washed with water. The foul straw used as litter is twice a week removed, and thrown into the drain, and having been stirred about with the dung-rake, and well washed from the dung, is first laid on the edge of it to drain, and afterwards carried out of the building, laid in heaps to putrefy, where it is soon wholly decomposed into a black or brown fatty manure, *which is found, however, to possess no particular efficacy*, deprived as it has been by the washing of the excrement and urine.

When the drain is quite full it is well stirred, the sluice is opened, and its contents allowed to flow into the tank; and the same process is again repeated, till the tank is quite filled. On large farms there is a great reservoir into which the mixture is pumped from the tank when full, and allowed to putrefy from four to six weeks, according to the temperature of the air. Sulphate of iron is frequently added, and is found to improve the manuring properties of the liquid.

Mode of application.

These liquid manures, consisting either of urine alone, of urine and water, or of urine and water in which the solid excrements have been dissolved, are applied to meadows and clover-fields in the spring, and after cutting the crop; they are also applied to the wheat-crops in winter and spring, and to barley and rape even when a foot high. Liquid manure may be used with advantage to every crop; but never produces so great an effect when applied before sowing, as when the plants are in some degree grown; because the carbonate of ammonia, when no vegetation is present to take it up, is either lost by evaporation, or washed away by the rain. It is particularly adapted for giving an impluse to a weak crop. In the application of urine, and still more so in the use of that in which the solid excrements have been dissolved, care must be taken that in pumping it into the barrel no agitation takes place, because the undecomposed particles consisting of vegetable fibre form an incrustation on the leaves of the plants, which is prejudicial, and renders them distasteful to the cattle. In summer it should be applied only in wet weather, otherwise the plants when the soil is dry receive the nutriment in a concentrated form, which is injurious to them. This may be obviated by dilution with a larger quantity of water, but the carriage is thereby increased. Liquid manure is best conveyed to the field in water-carts consisting of a pair of shafts and two wheels, carrying a cask containing from 60 to 120 gallons. The wheels should be broad to prevent their cutting into the land when drawn over growing crops. In

the under part of the barrel is a hole two or three inches in diameter closed by a valve, which the driver opens when required, by means of a string passing through the upper part of the cask. Under the hole is a board, placed in a somewhat slanting position, by which the liquor is spread as it flows out of the cask.

To what Soils and Crops applied, and in what quantity.

Light soils are found to derive more benefit from the application of liquid manure than clays and strong loams, in which the urine requires a longer time to penetrate, and consequently more of the carbonate of ammonia escapes. For the same reason it is very unprofitable, as experience has shewn, to draw in the land during a black frost. On sandy soils urine has a tendency to bind them together, while dung only renders them more porous.

The quantity used varies from 30,000 to 45,000lbs. the English acre. On light soils, from 27,000 to 30,000 lbs. is considered sufficient.

SECTION VI.

MANURES—NITROGENOUS MANURES CONTINUED.

Advantages and disadvantages of liquid manure—our present mode of managing farm-yard dung — capable of improvement—the drainage of it should be preserved for use—mode of fixing its ammonia as a sulphate—night-soil the richest in nitrogen of all manures — different modes of preparing it—improvements proposed by Liebig —other nitrogenous manures—muscles and star-fish—guano—bones—practical details of their use on grass-land in Cheshire.

Advantages and Disadvantages of Liquid Manure.

The advantages attending the use of liquid manure may be stated as consisting in,

1. The quickness with which the crop receives nourishment, from its being all dissolved in water, and in a fit state to be taken up by the roots.

2. A quicker return of capital than by the use of farm-yard manure, no more being applied than is sufficient for the wants of the growing crop, instead of manure enough for several crops having to be collected and laid on at once.

3. The saving of that portion of the most valuable part of manure which is washed away by rain during its preparation in the homestead, whilst lying in the land for several years, and when exposed on the surface as a top dressing.

4. The increased growth of forage plants, such as clover, lucerne, and the meadow-grasses, and the consequent increase of manure by summer soiling.

The particular advantages of dissolving the solid in the liquid excrements, as practised in the Black Forest and Switzerland, are,

1. The water in the drain within the cowshed absorbs much of the carbonic acid given out by the breathing of the animals, and thus prevents the escape of much ammonia.

2. The water in the drain keeps the shed cool during the heat of summer, and occasions a dampness in the atmosphere, which is better for the health of the cattle than a hot dry air.

3. The mixture of a large quantity of water prevents the escape of ammonia generated during the putrefaction of the urine, and promotes its conversion into carbonic acid.

4. The saving of litter.

The principal disadvantages attending the use of liquid manure are,

1. The difficulty of hitting off exactly the proper quantity to be used, and the danger of applying too much.

2. The difficulty of effecting its equal distribution over the field.

3. The loss of ammonia during putrefaction, unless much diluted with water, which loss perhaps is not much less, except under very good management, than that which takes place during the preparation of stable-dung.

4. The expense of constructing tanks, and the increased carriage of the liquid if much diluted. This cost, however, does not appear an objection of very

great weight. Sprengel calculates that 20,000lbs. of urine putrefied six or seven weeks contain from 800 to 900lbs. of actual manuring matter, while the same amount previously diluted with an equal quantity of water, contains (the water added of course not being reckoned) 1,400 to 1,600lbs. Therefore, if we take as the average quantity of urine required for an English acre of light land 30,000lbs. (answering to 20,000lbs. to the German acre), these 30,000lbs of urine putrefied without dilution will contain 1,275lbs. of manuring matter, and this same quantity of urine diluted with an equal bulk of water will yield 2,250lbs. diffused through 60,000lbs. of fluid; consequently, to apply 1,275lbs. of actual manuring matter, we must use 34,000lbs. of the diluted liquid. Let us now compare the amount of cartage required under this system with that necessary for manuring an acre of land with farm-yard manure, under the four-course rotation: using 20 tons of rotten dung per acre for turnips—half the turnips being drawn and the rest fed off by sheep, and the young clover dressed with 10 tons per acre of rotten dung. The quantity of manure required for the four crops will be 30 tons, or 7½ tons per annum.

To raise the same crops with liquid manure would require,

	lbs.
For the turnips, a full dressing, given perhaps at twice, viz. at sowing, and when up ...	51,000
Barley, half the turnips having been fed on the land	
Clover, dressed with	34,000
Wheat, a light dressing.....	17,000
	102,000

or not quite 46 tons, that is 11 tons and a half per annum, which is 4 tons a year more than would be required with the use of farm-yard dung. At the same time it is probable that the liquid manure thus applied would produce the largest crops, and that the Flemish practice of trotting from the field with the empty cart would compensate for the extra cartage, were it even greater, by the greater quantity of work performed in a day.

In those countries where liquid manure has long been used, it is in great repute among practical men, and whoever would persuade them to abandon it would stand quite as much chance of being scouted as theorists, as they who in this country recommend the use of it. Wherein does the difference consist, and how does it happen, that what is practical in Belgium or Germany becomes "all theory" in England? Oxygen, carbonic acid water, and nitrogen, are the same all over the world; the same kinds of plants contain the same elements wherever they grow; almost every country contains a variety of soils, each of which finds its counterpart in other countries. All the nourishment which plants receive from the soil they take up in a state of solution. If manure is found to be most economically and beneficially applied in a liquid state in a country possessing a climate so much like ours as Belgium, it can only cease to be so in England from causes unconnected with soil and climate. In a country, for instance, where labour is dear, the outlay required for the formation of tanks, and the expense of preparing the liquid, may render a process unprofitable which is advantageous in another country where labour is cheaper. The use of liquid manure, and its preparation, require much care and

attention, not only to insure benefit to the crops, but to prevent injury to them: it may easily be applied too fresh, or too stale—in too large, or too small quantities; and this care and attention to minutiæ are more likely to be found on small farms of 30 or 50 acres, like those of Belgium, where the cultivator is his own labourer, than on farms of ten times that size, where much must be trusted to servants.

Our present mode of managing Farm-yard Manure capable of improvement.

At the same time the waste of the most valuable part of farm-yard manure is so great under the English system, as to render it desirable, that without abandoning the use of it for that of liquid manure, till the superiority of the latter has been fully proved by experiment, the farmer should endeavour to introduce improvements in the present management of it, based upon a knowledge of the chemical properties of the substance with which he has to deal, by which a vast amount of manure may be saved, which is now lost. Not contented with promoting the escape of as much ammonia as possible in the volatile form during the process of heating, turning, and spreading the dung, and during the time which it is frequently allowed to lie on the land before it is ploughed in, we appear to endeavour to deprive it as much as possible of all soluble matter, by making the dung-hill the channel through which all the water which is collected from the roofs of the buildings passes by the main drains of the farm-yard into the nearest stream.

The Drainage of Dunghills should be preserved in tanks.

The annual waste of manuring matter which takes place on most farms, from this mode of management, is immense. In order to prevent it, the eaves of all the buildings should be supplied with spouts which would lead the water away, without allowing it to reach the dunghill, which should receive, except in very dry weather, only the water which falls on it directly from the atmosphere; and a drain should convey the surplus moisture from the dunghill to a covered tank, in which it should be preserved for use in a separate state. The brown or blackish fluid thus collected will consist partly of urine, partly of rain-water, with many dissolved particles of the solid excrements. It must be putrefied before it can be used, in order to neutralize the caustic ammonia, with carbonic acid; but if putrefaction be allowed to proceed so far that the smell of ammonia is entirely gone, it will have lost the greater part of its manuring properties. It will be better however to convert the ammonia into sulphate of ammonia during the process of putrefaction, by means either of sulphuric acid or gypsum. The liquid thus prepared may be applied, by means of the water-cart, to some of the most accessible of the growing crops, but only during wet weather; for holding, as it does, so many salts in solution, it may convey too much nutriment to the plants, and injure instead of benefiting them, should the ground not contain moisture enough to dilute it properly. If it contain more than 4 or 5 lbs. in the hundred of solid matter in solution, it will be too concentrated to be applied with

safety to growing crops in dry soils. If derived from a manure-pit flooded by rain from the roofs of the buildings, it will scarcely contain two per cent. of solid matter, and will then be of little value.

If the farmer dislike the use of the drainings of the dunghill in a liquid state to growing crops, they may be distributed upon uncropped land immediately before ploughing or harrowing it, or they may be used for the purpose of saturating heaps of compost; but to such compost, and indeed to any, containing, like all dungheaps, salts of ammonia, burnt lime should on no account be added, as it decomposes most of the salts of ammonia, and causes the escape of volatile ammonia.

Mode of fixing the Ammonia by means of Sulphates.

The dungheap thus freed from superfluous moisture, and the fluids which drain from it being preserved for use, instead of being got rid of as a nuisance, the next object is to provide that during the heating of the dung, and the subsequent management of it, as little ammonia shall escape in a gaseous form as possible. The best mode of fixing it appears to be by means of gypsum. Liebig recommends the strewing of the floors of stables and cowsheds with it, for the twofold purpose of removing the offensive smell, which must always be more or less prejudicial to the health of the cattle, and of preventing the escape of the ammonia in the form of the volatile carbonate. Gypsum and carbonate of ammonia cannot be brought into contact at ordinary temperatures without mutual decomposition, and the production of the non-volatile sulphate of ammonia and of carbo-

nate of lime. It is stated in a note by the editor of Liebig's work, that the practice thus recommended prevails in some parts of England. In Germany, according to Sprengel, it is usual to strew gypsum over land on which sheep are folded, in order to fix the ammonia of their dung and urine in the soil.

The dungheap might also be strewed with gypsum for the same purpose. It is a very cheap substance, easily obtained in most parts of England. Considerable beds of it exist in Cheshire, Derbyshire, and near Watchet on the Bristol Channel, and it might be raised in much greater quantities than at present, if there were a demand for it. Of the quantity that would be required upon a farm for those purposes, we may form a rough estimate, by supposing that for every horse or head of horned cattle kept as much ammonia is lost in a volatile state, by our present mode of managing farm-yard manure, as Sprengel calculates is lost in Belgium by putrefying urine without diluting it with water, or saturating it with acids, viz. 162 lbs., requiring for its saturation 373 lbs. of sulphuric acid. This quantity of sulphuric acid might be obtained from somewhat more than 5 cwt. of gypsum. But as the cattle are not in the yard above six months in the year, this would be reduced to $2\frac{1}{2}$ cwt. per head, which should produce $2\frac{3}{4}$ cwt. of sulphate of ammonia—a powerful manure, not to be bought for less than 25*s.* the cwt. Of course, however, if the dungheap is to be flooded with water, which will carry this soluble sulphate away from the farm, its formation by means of gypsum will only incur an unnecessary expense.

Nightsoil.

It has already been stated that human urine contains much more nitrogen than that of horses and neat cattle. The solid excrements are also richer in that element, which varies from 1¼ to 5 per cent. When fresh ⅘ of their weight consists of water. One hundred parts of the dried excrements yield, by incineration, 15 parts of ashes, consisting chiefly of the phosphates of lime and magnesia. One hundred parts of human urine are equal to 1,300 parts of the fresh dung of the horse, and 600 parts of that of the cow. The amount of the liquid and solid excrements of each individual cannot be estimated at less than 547lbs. during the year, containing on an average 16.41lbs. of nitrogen, or 3 per cent.; a quantity sufficient to supply the nitrogen contained in 800lbs. of wheat, rye, or oats, or 900lbs. of barley. This is as much nitrogen as it is necessary to add to an acre of land in order to obtain, with the aid of that absorbed from the atmosphere, the most abundant crops, and, at the same time, this is the manure which contains the largest amount of phosphates, so essential to the production of grain. Plants derive phosphoric acid from the soil. In the bread, fruits, and flesh which they eat, animals are supplied with the phosphates necessary for the formation of the bones and other parts of the body which contain phosphoric acid. The excess passes off in the urine and solid excrements. The bran of wheat contains much phosphoric acid, and therefore the refuse bran used in calico-works is well adapted for manure. The concretions found in the intestines of horses which live much on bran consist principally of phosphate of magnesia. Ten thousand parts of the straw of wheat

contain 47.3, and the same quantity of the grain of wheat 99.45 parts of phosphates. The leguminous plants, though they surpass all others in the quantity of nitrogen contained in them, are remarkable for the small amount of any kind of salts which they yield. In the ashes of the Windsor-bean, for instance, there are no free alkalies, and not 1 per cent. of the phosphates of lime and magnesia, while the stem of lucern contains only 0.83 per cent. of phosphate of lime and albumen. Buckwheat dried in the sun yields only 0.681 of ashes, of which 0.09 are soluble salts. In the above facts we see the value of these plants as fallow crops, since they do not exhaust the soil of any alkalies, and deprive it only of a small portion of its phosphates. In the tubers of potatoes the phosphate of magnesia and ammonia, with a little potash, are the principal inorganic constituents; and though the whole of the stems be returned to the soil, the phosphates require to be replaced by some manure containing them. That which contains the most of them is night-soil mixed with refuse bran, ground (not burned) magnesian limestone, or coal-ashes. Liebig raised a very large crop of potatoes with a dressing of nightsoil and Epsom salts (sulphate of magnesia). The nightsoil was mixed with coal-ashes and vegetable mould, till it acquired the consistence of a thick paste, and was dried by exposure to the sun. The quantity of this valuable manure annually wasted in England is incredible. It has been calculated that the sewers of London discharge daily into the Thames 115,000 tons of this and other solid and liquid manures, which in Belgium are carefully collected. We are too fastidious to suffer the bread which we eat to derive its nitrogen from so filthy a source, so we turn it into the Thames, and drink it, as the French say, *au naturel*.

One of the chief obstacles which have hitherto impeded the use of nightsoil as a manure, is the difficulty of removing its fetid smell, and rendering it portable, without, at the same time, dissipating its ammonia, and thus depriving it of a great part of its fertilizing properties. In Paris it is removed from the tubs in which it is collected in the houses to trenches in the suburbs, where it remains till it has attained a certain state of dryness, but ammonia escapes during the process with the water which evaporates, leaving little but phosphate of lime, and phosphate and lactate of ammonia, with traces of urea and fatty matter. It is also prepared, by the addition to it while fresh, of wood-ashes and earth, both of which contain much caustic lime. This removes the smell, but at the same time decomposes all the ammoniacal salts, leaving nothing but the phosphates. In London it has long been dried on plates of iron by means of artificial heat, after having been first prepared by one or other of the above processes. More recently a patent has been taken out for its preparation, by mixing it with calcined mud and finely-divided charcoal. By these the odour is instantaneously removed, while they retain the ammonia, by means of a power they have of absorbing that substance. But still, much of the ammonia is expelled by the heat employed to evaporate the moisture. Liebig recommends the addition of a cheap mineral acid to the nightsoil, before mixing it with the above ingredients. He also suggests, as the most cheap and practical method of fixing the ammoniacal salts of nightsoil and urine, and at the same time of rendering them portable, to mix them with the ashes of peat or coal, selecting, when the latter are used, such as are porous and earthy, with the addition of magnesian limestone or Epsom salts.

OTHER AZOTIZED OR NITROGENOUS MANURES.

Butcher's offal, consisting of the blood and intestines of animals, is a powerful manure, from the nitrogen which it contains—so powerful that it cannot be used alone, but must be mixed with some other substance the action of which is less energetic.

Wool, hair, bones, horns, and hoofs, also contain nitrogen, together with phosphates. Sprats, pilchards, and herrings, are extensively used on the coast. In the estuary of the Thames large quantities of muscles and star-fish are dredged up to be sold to the farmers for manure; and this branch of industry affords employment to the oyster-dredgers, who would otherwise be in great distress, in consequence of the mismanagement by which many of the public oyster-grounds have been ruined. Muscles are sold at 16*s.* the waggon-load, and star-fish, or five-fingers, as they are called, at 24*s.*; the latter are preferred, and a smaller quantity of them is used to the acre. The animal of each of them contains nitrogen, and the shell carbonate of lime, the superiority of the star-fish is probably due to the presence of phosphate of lime.

There are many parts of the coast in which these would afford the farmer a great addition of manure, and at the same time improve the condition of that hardy race of fishermen which furnishes so large a supply of seamen to our naval and commercial marine. At the mouth of the Conwy, in North Wales, are large beds of muscles left dry at low water, the collection of which, for the sake of the small pearls found in them, affords employment which is considered worth following by many of the neighbouring peasantry.

The muscles are boiled on the sands in order to cause the shells to open, and the pearls are found at the bottom of the cauldron. Great heaps of the shells are piled up near the boiling places, and I never heard of the animals being used in the neighbourhood as manure.

Guano.—A manure has long been used under this name on the barren soils of South America. It is the dung of sea-fowl which frequent the Guano Islands on the coast of Peru in immense flocks, and in the course of ages have deposited a stratum of excrements some feet in thickness. Astonishing accounts are given of the crops of maize and potatoes produced by it on the most steril land in South America. Considerable quantities have lately been imported into Liverpool for the use of the farmers of this country, both as a top-dressing for corn, and to be drilled in with turnips; for the latter it has been used with great success, at the rate of 2 cwt. to the acre, and promises to form a valuable addition to the list of powerful manures concentrated in a small bulk, and therefore easy of carriage. It has a urinous smell like that produced by the evaporation of urine, and like it consists chiefly of ammoniacal salts, the urate, oxalate, phosphate, and hydrochlorate of ammonia, together with the double phosphate of magnesia and ammonia, phosphate and oxalate of lime, the sulphates of potash and soda, about 4½ per cent. of clay and sand; together with various other substances, not estimated separately, such as water, soluble salts of iron, and organic matters insoluble in water, amounting altogether to 12 per cent.

Bones.—The manuring powers of ground bones are due partly to the presence of the nitrogen of their

gelatine (when it has not been extracted by boiling), and partly to their phosphates of lime and magnesia. The constituents of bones, according to the analysis of Berzelius, have been already stated. Liebig estimates the amount of nitrogen contained in the 32 or 33 per cent. of gelatine at 5.28 in 100 parts of that substance, and consequently that 100lbs. of bones are equivalent, as a nitrogenous manure, to 250lbs. of human urine. He further estimates that 8lbs. of bone-dust contain as much of the phosphates of lime and magnesia as 1,000lbs. of hay or wheat-straw, and that 2lbs. contain as much of these phosphates as 1,000lbs. of the grain of wheat.

When reduced to fine powder and moistened bones generate heat; their gelatine is decomposed and converted into the carbonate and other salts of ammonia, which are retained in a great measure by the powder itself. He recommends, as the best mode of their application, that they should be wetted, in a state of fine powder, with half their weight of sulphuric acid diluted with three or four parts of water, and after they have been thus digested for some time, and 100 parts of water have been added, that the mixture should be sprinkled over the field before the plough. The free acids unite immediately with the alkalies existing in the soil, and form neutral compounds. Corn and kitchen-garden crops throve vigorously in a soil consisting of decomposed grauwacke (a sandstone of the slate series), when thus manured. The superior efficacy of boiled to unboiled bones he attributes to the removal of the fatty matter, by boiling, the presence of which impedes the putrefaction of the gelatine. As a substitute for bones he recommends the employment of a similar solution of phosphates in muriatic acid, the

refuse of glue-manufactories, many hundred tons of which are annually thrown away. In consequence of this suggestion, this glue-refuse has recently been tried as a manure for turnips with the best success.

Bones have long been used in Norfolk for turnips, drilled in with the seed, at the rate of 20 bushels per acre, but are now getting rather out of repute in some parts of that county, partly perhaps because the ground from their repeated use contains as much of the phosphates as the crops grown on it require, and therefore an additional dose produces no effect, and partly on account of a disease with which the sheep have been affected, and which is supposed, whether justly or not, to be confined to the land which has been much dressed with bones.

Their Employment on Grass-land.

Bones have been used for many years in Cheshire as a manure for grass-land. The details of their application, as practised for the last ten years on the estate of Lord Combermere, are given in the second volume of the Journal of the Agricultural Society. The land on which they are found to succeed best is old sour turf on a clay not worth, in its original state, more than 10*s.* or 15*s.* the acre. On new land that has not been in grass nearly seven years they are not considered to answer. The time of application is the beginning of April, and no stock are put on the land till the following spring. The quantity used on an acre is from 30 to 35 cwt., worth 135*s.* the ton; or, if bought by the bushel, 2*s.* 3*d.* the imperial bushel, weighing from 45 to 47 lbs.

Boiled bones are cheaper, but are in general not *considered* to answer so well; though it is stated that no difference was observable on two portions of the same field, dressed, the one with boiled, the other with unboiled bones. Fresh bones boiled are considered preferable to old bones unboiled. They are ground coarse, about the size of a walnut. Land previously worth 10*s.* to 15*s.* the acre has thus been rendered worth from 30*s.* to 40*s.* The bones are laid on at the expense of the landlord, the tenant paying 7 per cent. on the outlay. Part of a mowing field, dressed with 35 cwt. to the acre eight years ago, has produced crops of hay every year equal in quality to those of another portion of the same field dressed with good farm-yard dung. On pasture-land the effects of the bones are visible for twenty years, though the produce is considered to have been falling off for the last five.

Here then we find that 3,920 lbs. of bones during fifteen years, or 261 lbs. per annum, have produced effects equal to a dressing of good farm-yard dung each alternate year, which cannot be considered less than five tons per annum. How were these effects produced? The bones did not act by magic. What were the substances which the land received with them?

Unboiled bones contain 33 per cent. of gelatine, (yielding 5.28 per cent. of nitrogen,) 52.20 per cent. of the phosphates of lime and magnesia, and 11.30 per cent. carbonate of lime, and in these, with the exception of a trifling proportion of soda, their manuring powers must be sought. 261 lbs. of bones contain 86.13 lbs. of gelatine, (equal to 4.54 lbs. of nitrogen,) and 136.24 lbs. of phosphates, and 29.50 lbs. of carbonate of lime, answering to 16.5 of lime.

Hay containing 1 per cent. of nitrogen, the 4½ lbs.

of nitrogen would produce 450lbs. of hay; and 8lbs. of bones, containing as much phosphate of lime and magnesia as 1,000lbs. of hay, 261lbs. of bones ought to contain as much of these phosphates as 32,625lbs. of hay.

The results therefore appear greater than can be ascribed to the gelatine of the bones, while the phosphates are largely in excess. In the absence of more definite information as to the constituents of the soil than that it was an old sour turf upon a clay subsoil, it is impossible to say what effect the carbonate of lime may have had. If the sulphuric or hydrochloric acids were present, the 16.5 of lime contained in it might have formed 50lbs. of gypsum, or a corresponding quantity of chloride of lime, and the nitrogen which the gypsum would have attracted from the atmosphere and fixed, would have been sufficient for the production of about 800lbs. of hay.

On the whole, notwithstanding the great benefit derived from the use of bones in the above quantity, there is reason to suppose that a more economical mode of application might be devised, by using them in smaller quantities, mixed with some nitrogenous manure—sulphate of ammonia for instance—of which 112lbs., worth about 25*s*., contain 21lbs. of nitrogen.

SECTION VII.

MANURES CONTINUED.

Gypsum—peat-ashes and coal-ashes—reasons of the apparently capricious action of gypsum—instances of great crops produced by it—nitrate of soda and potash—fallowing—fallow crops—irrigation.

Gypsum—Peat-ashes—Coal-ashes.

The abundance of gypsum in various parts of England, and its indirect influence as a manure by decomposing the carbonate of ammonia contained in rain-water and in putrefied urine, and fixing it in the soil in the form of the sulphate, have been repeatedly mentioned in the preceding pages. It acts, however, in a direct manner, by entering into the composition of those species of plants whose ashes contain it in larger proportion than that in which it is found in many soils.

The use of gypsum as a manure commenced in Germany during the latter part of the 18th century, and it has long been extensively employed in America. In consequence of the benefits said to be derived from it in those countries, experiments were made with it in England; many of which failed, either from its having been applied to crops which did not require it, or to soils which contained it in sufficient quantity for the wants of those plants of which it forms a constituent. These are red-clover, lucern, saintfoin, rye-grass, and turnips.

Apparently capricious action of Gypsum.

Of these, gypsum greatly increases the crop upon soils which are deficient in it, while on wheat, barley, oats, which either do not contain sulphate of lime, or contain it only in small quantities, it produces no benefit whatever. This apparently capricious action has operated to prevent the general use of a manure, the judicious application of which is likely to be of the greatest benefit to the farmer, from its cheapness both as regards original cost and carriage, and from the facility with which it can be procured in most parts of England. The proper time for using it is toward the end of April, or first days of May, and from its sparing solubility it requires to be sown in wet weather. An ordinary crop of clover or saintfoin contains 2 cwt. of this salt, and that is the maximum quantity which the farmers in Kent and Hampshire have found to be beneficial. Gypsum is so cheap, the expense of dressing an acre at this rate being only 7*s.*, that there is no great risk even in an unsuccessful experiment; and on the other hand, the farmer may be certain that these 7*s.* will be well laid out, even without having an analysis of his soil, when he finds that land which once yielded good crops of clover and saintfoin begins to fail, or to become "clover sick," the young plants springing up in abundance, but dying off as the summer advances, and that good crops can only be obtained once in ten or twelve years.

Instances of great crops produced by Gypsum.

The following account by C. W. Johnson, Esq., of the experience of himself and others in the use of

gypsum, will, it is hoped, induce a trial of it by those who have never had an opportunity of witnessing its effects[1]. "In an old grass paddock," says Mr Johnson, "of about 70 acres, in the Vale of Kennet in Berkshire, the grass-land for many years gradually became less and less productive; and this in spite of all kinds of applications; the earths (such as clay and chalk), and farm-yard compost, had all been liberally and repeatedly spread without producing any thing like a luxuriant crop; but it was found at last that the peat-ashes of the banks of the Kennet, when spread at the rate of about 40 bushels per acre, produced the very best results—an excellent crop both in weight and colour—certainly more than a ton of hay per acre beyond what the soil had yielded before. The fact was now evident that it was gypsum that the soil needed; for as these peat-ashes contain about 12 per cent. of sulphate of lime, more than 2 cwt. of gypsum was conveyed on the land with them; it constitutes, in fact, by far the chief fertilizing ingredient in these peat-ashes; the remainder being about 40 per cent. of sand, and the rest chalk, red oxide of iron, and a small quantity of common salt." If this conclusion, therefore, was correct as to the gypsum being the only valuable portion of the peat-ashes, it was certain that an application of 2 cwt. per acre of gypsum to the same land would produce similar beneficial results: and upon trial it was found that benefits, fully equal to any yielded by the application of peat-ashes, resulted. Two cwt. per acre of gypsum in fine powder was spread on a portion of the grass with the most beneficial effects; the grass not only grew with greatly increased vigour, but a

[1] Journal of Royal Agricultural Society, Vol. II. p. 109.

quantity of white clover and other grasses made their appearance on the portion dressed, in so marked a manner as to attract the attention of the tenant to the fact. The soil on which these experiments were made consists of

Organic matter, chiefly vegetable	3.5
Soluble matters	3.0
Carbonate of lime and magnesia	19.0
Oxide of iron	2.75
Alumina	8.5
Sand and gravel	62.0
	98.75

This is about 10 inches deep, and it rests on a thin stratum of gravel, and then chalk.

"There is another fact which clearly supports these conclusions; viz. the great use of common coal-ashes as a top-dressing to clover, saintfoin, and lucern: there is no manure so universally in possession of the farmer equal to them for their immediate effect upon those grasses. Now coal-ashes usually contain about 10 per cent. of sulphate of lime, and therefore a dressing of 50 bushels of coal-ashes per acre is equal to an application of about 5 bushels of gypsum; the remaining portion of the ashes consists principally of about 10 per cent. of lime and sand, and a small portion of red oxide of iron and alumina; so that the gypsum is evidently here again the active ingredient; the other constituent parts being nearly inert substances[1]. My own experiments and observations have been confirmed by many others within the last two years; for gypsum is evi-

[1] Not entirely so, for both alumina and oxide of iron act indirectly by absorbing ammonia.

dently creeping gradually into use as a manure for the grasses. Mr James Barnard, an excellent and extensive farmer of Little Bordean, in Hampshire, in a recent communication to me, thus describes his experience with gypsum.

"'The soil of my farm is of a clayey nature, and would be very stiff but for the number of stones that are in it. I have sown gypsum six or seven years, and never on clover or saintfoin without satisfactory proof of its efficacy, having usually grown half a ton more of hay per acre by its use. But the effects in 1838 were wonderful. I put on 2½ cwt. per acre, on a two-year old piece of saintfoin, on the first of May, with the plants very forward, just leaving the ground and coming to stalk. The gypsum had so increased the growth by the 9th of the same month, that, when crossing the land with a friend, we observed the difference from one of the fields to the other; and, at harvest time, the extra produce of hay was quite 1 ton per acre. I then laid the field up, and cut it again in October, when the effect of the gypsum was still more apparent, there being 1½ ton of hay per acre on the so dressed portion of the field, and scarcely any on the remainder of the land. Cutting the saintfoin twice in one year, and the enormous produce, brought a great many persons to look at the field, who all declared that they had never seen the like before. On the same piece this year (1839) I did not use gypsum, thinking it would be quite good enough without, and the difference was quite as great. I mowed twice the gypsumed ground, but there was nothing to cut on that which had not the gypsum. I can even see the effect where three years ago the gypsum was spread; as I always leave a strip or two in every field to prove the effect.

" 'There is one thing more I wish to observe, that I never put on gypsum before the last week in April, or the first in May, and choose, if possible, a moist morning. I have not found much good effect from its application on either chalk or cold clay soils.'

" Mr Smith, of Highstead, found still greater benefit from the use of gypsum to his clover leys, for where the simple soil produced only 1 ton per acre of hay, the portion of the same soil, to which 5 bushels per acre of gypsum had been applied, yielded 3 tons; the first producing only 20lbs. of seed, the latter 105 lbs."

Nitrate of Potassa and Nitrate of Soda.

The use of nitrate of potash, or saltpetre, as a manure, commenced in Norfolk several years ago, and applied at the rate of about 1 cwt. an acre, it was found to produce an increased produce, varying from 3 bushels to 8 per acre. Its general use by the farmer would enhance the price too much to admit of its being applied with profit; but nitrate of soda is so abundant as a natural production of the earth in South America, that it may be procured in almost any quantity that can be required.

From the account of a number of trials made with it in different counties, on a variety of soils, and on different crops, detailed in the second volume of the Journal of the Agricultural Association, it appears to have been attended with very unequal results; in some cases amply repaying the farmer by an increase of grain and straw, in others, barely reproducing its own cost; in some, causing positive loss and actual detriment to the crop. On wheat, by the application of from 1 to 1½ cwt., worth 26*s.* per cwt., an extra produce of 8

bushels, and 238lbs. of straw was obtained in the most successful cases; and some large farmers have been so satisfied with the results, as to dress 100 acres and even more with it. On oats and barley it is in general more successful than on wheat. It is thought to answer best on light soils, but there are instances of its successful application on clay, and also on calcareous soils, as well as of its failure on each. On wheat it appears to produce the same effect as putrefied urine, soot, and gas-liquor, (all substances containing ammonia,) causing abundance of long but at the same time weak straw, an increase in the quantity of grain and (as far as experiments have gone) of gluten, but a diminution of its weight.

The cases of failure appear to have taken place when the nitrate was applied too early, or in very dry weather, or on land full of condition, and therefore capable of producing a good crop without it. On such land it causes blight.

On turnips, clover, grass, and all crops requiring nitrogen, it appears to have been very generally attended with success. The quantity used is from 1 to 1½ cwt. the acre. The time of application from the middle of April to about the tenth of May, and on oats to the end of that month. It is most certain in its effects when sown in showery weather, or immediately after rain. Some farmers sow half the quantity when the wheat first begins to feel the effects of spring, and the rest about six weeks afterwards. Those who have found the greatest benefit from it on turnips, consider that it is better applied as a top-dressing, a few days after sowing, than by drilling it in with the seed.

Nitrate of soda may act in two ways; either plants may decompose the nitric acid, and thus obtain nitro-

gen, as we know that they obtain carbon by the decomposition of carbonic acid, which the chemist finds infinitely more difficult to decompose than nitric acid, or its fertilizing qualities may be due to its alkaline base. The former view derives strength from the increase of straw and gluten, the dark green colour of the leaf, and lightness of grain, which the nitrate produces, while the capriciousness of its action looks as if the effects of the nitrate were due to the alkaline base, and its failure to the presence of alkali in sufficient quantity for the wants of the crop on those soils on which the nitrate produces no results. These points, however, Liebig observes, can only be cleared up by more accurate experiments than any which have yet been recorded, by analyses of the soils on which it fails and succeeds, and by comparative analyses of the wheat grown with nitrate of soda and potassa, in order to determine whether a mutual substitution of their respective bases is effected.

FALLOWING.

In a former part of this work the insolubility of humus or mould has been insisted on, and the arguments have been adduced by which Liebig may be considered to have proved that its carbon is taken up by plants in the form of carbonic acid. This insolubility, he observes, is a wise provision of nature, for if the humus of the soil possessed even a smaller degree of solubility than that of humic acid, soils would be liable to be deprived of it by a long-continued rain; but as it is only soluble when combined with oxygen, it can only be taken up by water as carbonic acid. Its conversion into carbonic acid is an extremely slow process. To the decay of humus moisture and access of

air are necessary; and it only proceeds when plants grow on the soil in which it is contained, because the roots then absorb the carbonic acid as it is generated; whereas an atmosphere of carbonic acid surrounding the particles of humus arrests the progress of decay by preventing access of oxygen.

The humus abstracted from the soil by one crop is restored to it again by the decaying leaves, and the excrements of the plants, more particularly some species of plants; and thus the proportion of carbonaceous matter contained in a soil increases under a proper system of culture.

The decomposition of animal and vegetable matter Liebig divides into two kinds: decay, which he calls eremacausis (or a slow combustion), and putrefaction. To the former a free supply of oxygen is necessary, the latter takes place when oxygen is excluded, or is not present in sufficient quantity. Putrefying matters in a soil are injurious to vegetation, by reason of their powerful tendency to de-oxidize every substance within their influence, for when the roots are deprived of oxygen plants cannot live; the same putrefying matters, when free access of oxygen has changed the putrefactive into the decaying process, supply plants with the carbonic acid necessary for their early developement.

The soluble matter which communicates to water a brown or yellow colour is humic acid, a product of the putrefaction of animal and vegetable matter, and is a proof that oxygen is not present in sufficient quantity to complete the decay. Instead of soils being fertile in proportion as they possess the power of communicating this colour to water, the reverse is the case. Plants do not thrive in a soil of peat which possesses this property in the greatest degree; and it

is universally agreed, among practical farmers and gardeners, that manure is best suited to the growth of plants when it ceases to discolour water.

These coloured solutions lose their colour by absorbing oxygen from the air, and at the same time they deposit a black coaly matter, which is the insoluble coal of humus. In a soil therefore abounding with humic acid, the demand for oxygen which it occasions deprives the roots of plants of an element so necessary to their existence, that they cannot grow in earth or water destitute of free oxygen, and its effects are the same as those of the hydrated protoxide of iron, which is injurious to vegetation because it deprives the roots of oxygen.

It follows that the object of fallowing, besides the destruction of root and seed-weeds, is the exposure of the organic matter contained in the soil to the action of the air, by which its decay is accelerated, and its conversion into carbonic acid promoted. The increased disintegration of the soil which this exposure to the weather effects, renders, at the same time, the alkalies which are locked up in it soluble and capable of being appropriated by plants.

Every gardener and farmer is aware of the benefit which plants derive from the soil around them being stirred and loosened, by hoeing and similar operations, during their growth. This arises partly from the mechanical effects produced on the soil, by which the fibres of the roots are enabled to penetrate it and to extend the sphere of their action, but is principally due to the chemical process above mentioned, by which the conversion of organic matter into carbonic acid, and the solution of the alkalies are promoted.

Fallow Crops.

Experience has proved, that however highly land may be manured, the same crop cannot be grown upon it with advantage several years in succession; and, on the other hand, that an abundant produce may be obtained with but little manure when certain crops, such as corn, are made to alternate with others, such as turnips, peas, clover, tares, &c., which are known to the farmer by the names of green or fallow crops. It has been found again, that the produce of some of these fallow crops is diminished if often repeated, and that the interval required between them varies with the soil. On some lands clover will not grow oftener than every sixth year; on others it must not recur more than once in twelve. It is therefore an object of the utmost importance to the farmer to establish such an alternation of crops as shall produce the greatest produce with the least manure; and to the attainment of that end, nothing will conduce more than a knowledge of the reasons which render this alternation necessary. This knowledge, however, can only be obtained by careful induction from accurate experiments, instituted in order to determine the substances contained in a given crop—what portion of them it derives from the soil, and what from the atmosphere; what substances it returns to the soil, and for what species of plants the matters so returned will serve as nutriment. This knowledge is not to be attained by assumptions or guesses, nor by hasty conclusions from a few loose experiments, and yet, strange as it may appear, there is no class of men more prone to this error—

more apt to jump at theoretical conclusions, than those who glory in the title of practical.

The facts connected with the alternation of crops, which have been established by experience, have engaged the attention of men of science, and have led to investigations made with a view of discovering the causes from which this necessity arises. The explanation first offered was, that the soil contained a variety of substances, some only of which could be assimilated by one family of plants, others by another, and that each plant absorbed those substances which were suited to it, and rejected the rest.

Subsequent observations caused the following modification of this theory—namely, that plants absorb indiscriminately whatever is presented to their roots in a state of solution, retaining that which is suited to assimilation by them, and expelling as excrement that which is unsuited. Some experiments of Macaire Princeps have been already mentioned, in which plants were made to vegetate in a weak solution of acetate of lead, and were sprinkled with nitrate of strontian. In each case they absorbed the substance thus presented to them, for it was detected by analysis in their structure, but they expelled it again. These experiments offered strong confirmation of the above views, and afforded a satisfactory explanation of the fact, that a plant, like wheat, which contains much potash, will not flourish after another crop likewise requiring potash, and that it thrives after clover, beans, peas, or other leguminous plants, which scarcely contain any alkalies; but they did not explain how land becomes fertilized by fallowing, nor how leguminous plants cause an increase of carbonaceous matter in the soil. Other experiments however made by him have established

the fact, that most, if not all plants, expel whatever their organs are unable to convert into woody fibre, starch, gluten, &c., and that these substances are of two kinds, inorganic matters derived from the soil, which are incapable of assimilation, and organic compounds formed in the plants by the vital process. He found, for instance, that when leguminous plants were grown in water it acquired a brown colour, that other plants of the same kind would not grow in this water, but that the plants of corn throve in it and removed some of the colouring matter. He ascertained, too, that of the organic matters thus expelled, some were of an acrid resinous nature, some mild, like gums, the former of which he regarded as poisonous, the latter as nutritious, to succeeding crops. These organic matters, thus expelled by the roots and deposited in the soil, restore to it the carbon, which in the early stages of their growth the plants had extracted from it in the shape of carbonic acid. Before they can be converted into nutriment for other plants they must undergo decomposition; their putrefaction must be converted into decay by the access of air, which tillage produces, and thus they become capable of performing the functions of humus, by affording a supply of carbonic acid. In calcareous soils, the process of decay is accelerated by the presence of lime, while argillaceous soils are those in which the longest time is required for its completion. The excrements of a given crop must be thoroughly decomposed before the land will produce another of the same species, and on those soils on which the longest intervals are required between crops of the same kind, it is found that the time cannot be shortened by the most powerful manures. Now calcareous soils are those on which peas, clover, &c. will

bear to be repeated at the shortest intervals, and argillaceous soils are those on which the longest periods are required between them. But though these excrements, undecomposed, either wholly or in part, are injurious to plants of the same species as those which expelled them; they are not so, nay, are even capable of affording nutriment to those of other species; and therefore the introduction into cultivation of every new plant which can supply the place of another, such as clover, or turnips, which will not bear frequent repetition, confers a great benefit on the farmer, by furnishing him with the means of varying and extending his rotation. Plants with tap-roots which strike deep into the soil, and with a large system of leaves, and which are consumed on the land before the seeds are matured, are the most useful in preparing the land for a corn-crop, whose roots do not penetrate deep, and whose seeds constitute their chief value. The roots of such fallow crops striking deep into the earth, bring, as it were, a new land into cultivation, by collecting, from a depth to which corn does not penetrate, substances, such as alkalies and phosphates, diffused through the subsoil, and which are thus brought to the surface and there deposited, partly in the excrements of the cattle by which the crop is consumed, partly, perhaps, in the excrements of the plants themselves; these latter certainly leave in the soil a considerable amount of carbon, which the extensive surface of leaves has enabled the plant to obtain from the atmosphere. Thus a judicious and extended rotation of crops, while it increases the amount of animal manure, enables the cultivator to obtain a maximum produce with less expenditure of it, by availing himself, as extensively as possible, of the excrements of plants.

Our system of agriculture is also susceptible of improvement, not only from a more extended rotation which shall enable us to dispense with the frequent repetition of certain crops, but from the employment of means which shall shorten the long intervals required between those crops on certain soils, by effecting a more rapid decomposition of the excrements which they leave behind them. On argillaceous soils, for instance, these effects will be produced by the use of lime, alkalies, and wood-ashes. In the attainment of these objects, the investigations of science are capable of affording valuable assistance to practical men, by discovering the causes which render certain modes of cultivation advantageous, and by directing their experiments in search of improvement into proper channels. These investigations can scarcely be said at present to have commenced. In order to the establishment of the most profitable system of rotation, it is necessary that experiments on new modes of practice should be accompanied by the most accurate possible analyses (such as have only lately been brought to this department of chemistry) of the soil, both before and after it has produced corn and fallow crops; of the manures applied, and of the difference in the constituents of the crop grown on the same soil, with or without those manures.

IRRIGATION.

On no department of agriculture are the principles developed by Liebig capable of throwing greater light than on the practice of irrigation. The benefits which grass land derives from it are well known; and when the water with which the meadows are

irrigated is much charged with the drainage of towns and farm-steds, the organic matter held in suspension affords an easy explanation of its efficacy to those who maintain that plants can only be nourished by means of organic matter; but this explanation fails to account for the advantages derived, though not to the same extent, from irrigation with colourless and apparently pure spring water; and therefore every practical man, who is cognisant of the fact, invents some theory of his own to explain it. Even Davy was inclined to ascribe much of the benefits of irrigation to the protection which the grass received when covered with water from the frosts of early spring. Let it however once be admitted, that inorganic salts are necessary to the well-being of plants, and promote an increased development of them, and the wonder ceases; for the water of the clearest springs holds in solution a number of these salts, such as carbonate, sulphate, and chloride of lime, with silicate and other salts of potassa and soda. Reeds and *equisetaceæ* thrive in ditches and streamlets, because a large portion of silicate of potassa enters into their composition, and, by the frequent change of the water, dissolved silica is largely supplied. The meadow-grasses likewise require silicate of potassa, and they are furnished with it by the water which flows over them while under irrigation. The carbon also, and the carbonaceous excrements of plants contained in the soil, require abundance of oxygen to promote their decay and conversion into carbonic acid. Now the water of rivers and streams holds oxygen in solution, and if, during the process of irrigation, the water be frequently renewed, no matter how thin the sheet of it with which the

meadow be covered, it will communicate large supplies of oxygen, and promote the decomposition of the organic matters contained in the soil. Stagnant water, on the contrary, retards their conversion into carbonic acid by preventing the access of air, and hence arises the sterility of bogs and marshes. In order to convert them into luxuriant meadows, it is only necessary to remove the stagnant water by draining, and, where practicable, to irrigate them by means of water rapidly renewed.

In warm climates irrigation is practised on arable as well as meadow-land, and is necessary to impart to the parched soil sufficient moisture to present plants with the salts which they require in a state of solution. In this country, where the humidity of the climate renders artificial supplies of moisture to the arable land superfluous, the practice of irrigation is confined to meadows, and performs the double office of supplying them with liquid manure in a state of great dilution, and of accelerating the decay of carbonaceous matters existing in the soil, by bringing them in contact with frequently renewed supplies of oxygen. Water-meadows are usually confined to low lands, with only sufficient fall to allow of the water being returned into the adjoining stream; and even in such situations, either from want of capital, or want of energy, or from the intermixture of property and the entails to which it is subject, full advantage is rarely taken of the means of improvement at command. But it is not to such lowland meadows alone that the benefits of irrigation are applicable. Experience has shewn, that the fertilizing properties of water are capable of converting the most barren upland wastes into productive meadows, and that these

are the situations in which irrigation can be applied with the greatest effect, from the quick circulation of the water over them which the fall of the ground allows. In such situations the benefit is not confined to the land actually irrigated; its influence extends to the adjoining arable land, which obtains from these meadows large supplies of manure, and is thus made to yield an increased produce. The water-meadows of the Duke of Portland at Clipstone, and of Lord Hatherton at Teddesley, have proved that few modes of investing capital hold out prospects of such certain and profitable returns*.

The Clipstone water-meadows are situated in the midst of Sherwood Forest, between the towns of Mansfield and Ollerton, and are watered by the little stream of the Maun, in its descent from the town of Mansfield. The Valley of the Maun in its original state was covered by bog 9 or 10 feet deep. The hill-sides varied in quality, but £80. would have been a high rent for the 300 acres; and the whole rent of the Clipstone Park Farm, containing 1487 acres, when taken in hand in 1816, did not exceed £346.

By means of two flood-dikes, one on each side of the valley, of the respective lengths of 5½ and 2 miles, the water was diverted over the dry and barren slopes of the hills, and returned into the stream of the Maun at a point nearly 59 feet below that from which it was originally derived. The number of acres watered is about 300, consisting partly of land of this description, partly of swampy valley. Each had to be prepared for irrigation by a peculiar process, the swamp by draining, the hill-sides by stubbing the gorse, paring, burning, draining, levelling and fallowing for

* See Journal of the Royal Agricultural Society, p. 359.

turnips, which were followed by barley, and that again by turnips. After the second (in some cases the third) crop of these, the land was sown with grass-seeds, on which when sufficiently strong, that is, when from one to six months old, according to the season, the water was turned.

The preparation of the swamp was the most expensive, and the results less satisfactory than on the hill-sides, where the water produced the greatest effects. Draining formed a very heavy item of expenditure in both cases, irrigation causing fresh and deeper springs to break out on land which previously appeared to have been laid sufficiently dry, and without effectual draining irrigation loses half its value. In order completely to cut off the springs, the bog-lands were drained to the depth of 12 feet, (sometimes more) by means of drains 3 feet wide at the top, and one foot at the bottom, at a cost, for cutting and filling, exclusive of tiles, of 1*s.* 4*d.* per linear yard. The best inclination for the surface appears to be a fall of 1 foot in 9. With this declivity it was found that the earliest and largest produce was obtained. On very flat parts near the river, where the flow of water was languid, the crops were found to be small, notwithstanding the superior quality of the land; thus illustrating the necessity already spoken of, for a supply of oxygen by means of water frequently renewed.

The water is allowed to remain on the newly sown grass about four days, and then taken off, and after the crop is mown the water is again admitted.

The same management is applied to the old sward, the water being turned on for three or four days at a time, at intervals of about a month or six weeks,

throughout the year. The time of keeping the water on varies however with the season and the state of the weather.

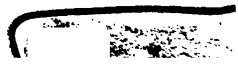
The produce of these meadows is very great, and is applied in the following manner. From January to the end of March, and sometimes even till late in May, they are fed with ewes and lambs, maintaining two couples to the acre. From April to the end of July two cuttings of grass are obtained, producing together 36 loads of green fodder per acre, which is consumed by cattle in the yards; and thus these 300 acres of water-meadow enrich nearly 1500 acres of arable land. If mown for hay the land yields two tons per acre, and is pastured so much later that four lambs per acre are fattened instead of two. On the whole, the net produce per acre, after deducting all expenses except rates and taxes, is estimated at £11. 14*s*. This improvement has been effected by means of an expenditure, for levelling, forming carriers, roads, bridges and stop-gates, of £39,297. The greatest effect is produced by irrigating the meadows after strong rains, when the water is charged with the drainings of the town of Mansfield; at those times it sometimes deposits a sediment in one watering equal in thickness to a sheet of paper. Mineral waters and waters from peat-mosses and bogs are stated to be injurious. Mineral waters, however, is rather a vague term, since it applies to those holding carbonate and sulphate of lime and alkaline salts in solution, which are decidedly beneficial. The pernicious effects of the water derived from peat-bogs and marshes arises from the presence of proto-sulphate of iron, which, instead of furnishing the grass with oxygen, abstracts it during its conversion into the peroxide. This evil,

however, might be remedied by exposing such waters to the action of the air for some time in reservoirs, where the proto-sulphate would acquire oxygen, and deposit a slime consisting principally of the hydrate of the protoxide of iron, which, when sufficiently pure, would be valuable as a yellow pigment, or might be converted into different shades of red by being further oxidized at a low red heat. The less pure portions, mixed with lime, form an admirable cement for setting under water; or, when converted into the peroxide, would have a beneficial effect on land. Such reservoirs would be attended with other advantages. They would furnish water-power for the working of machinery, and would supply a reserve of water for the purpose of irrigation during dry seasons, when it is of the greatest value. The sulphate of iron might in some cases be decomposed by mixing the water containing it with that derived from calcareous soils, which would contain carbonate of lime, dissolved in excess of carbonic acid. The sulphuric acid would quit the iron for the lime, and sulphate of lime would be formed.

At Teddesley Lord Hatherton inclosed and drained, during ten years, 467 acres, thereby increasing the rental from £254 to £689. The drainage water is conducted to a mill-pond, and thence to a water-wheel 30 feet in diameter, which turns machinery by which various operations are performed, effecting a saving of labour to the amount of £400 a year. After driving the mill, the water is joined by a carrier which brings down the drainings of the farm-yard. These and the alluvial matter brought by the mill-course mix in a tank, and the mixture is employed in irrigating 89 acres of upland meadow, which it has improved to the amount of £2 per acre annually. The total

expense of these operations was £2,733, and the total annual increase of value £1,013.

Of the advantages to be obtained by employing the sewerage of large towns in irrigating the adjoining lands, a remarkable example is furnished by Edinburgh, where hillocks of sand have thus been converted into the most fruitful meadows. Their produce, let every year by auction, in plots of a quarter of an acre and upwards, generally brings from £24 to £30 per acre, and in some instances even more. The clear profits of 110 acres for the year 1827 were £2,300.

We may judge how much the produce of this country might be increased by a general system of drainage, and by a judicious application of the sewerage of large towns to the purposes of irrigation, from the above facts, and by bearing in mind that it is a generally admitted estimate, that out of the 12,000,000 acres of arable land in England and Wales 10,000,000 require drainage; to which, in order to carry the system of irrigation as high up the hills as possible, 10,000,000 more of pasture land must be added. During parliamentary inquiries respecting the supply of water to the metropolis, it was calculated that 115,000 tons of liquid and solid manure were daily discharged into the Thames; and England and Wales contain 230 other towns, with populations varying from 20,000 to 262,000 inhabitants.

THE END.